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OUR OIL RESOURCES

OUR OIL RESOURCES

Edited by

LEONARD M. FANNING

Author of "The Rise of American Oil"
and "American Oil Operations Abroad"

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OUR OIL RESOURCES

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PREFACE

Petroleum as a source of energy probably yields only to atomic energy in public interest and discussion. As today's number one energy source, oil is vital to our national well-being and our national defense. Perhaps some day the atom will displace petroleum in certain energy fields, but that day has not yet come, and until it does our oil resources will remain a matter of greatest importance and concern to everyone.

This edition of "Our Oil Resources," is not only completely revised and up to date but considerably augments the first edition published in 1945. It is a larger, more comprehensive book and is more profusely illustrated.

As in the previous volume, it presents exhaustive studies of our oil resources by highly qualified authorities. Many of these experts are top executives of oil companies. In many cases they have enlisted the aid of their technical staffs in exploring and presenting the basic facts.

Two new contributors appear—Walter S. Hallanan, president of the Plymouth Oil Company, and Hiram M. Dow, former chairman of the Interstate Oil Compact Commission. As chairman of the National Petroleum Council, representing companies large and small and in all branches of the business in matters of liaison with the national government, Mr. Hallanan has appropriately written the leading chapter, The Role of Private Enterprise in the Development of Oil Resources. Mr. Dow has supplied the important chapter, Conservation of Our Oil and Gas Resources.

Changes in the technology of exploration and production since 1945 alone call for this new volume. When the first edition was published, the war had just ended; the oil industry had brought to stirring conclusion its magnificent contribution to victory, in teamwork with the government. The war found the American oil industry strong and ready to serve, having the two essential requisites for the emergency—reserves and know-how. It was able to supply some 90 per cent of the petroleum requirements of all the United Nations. When the war ended, necessary wartime restrictions were gradually removed. While technological improvements were vigorously pursued during the war, they were of special and restricted nature. The end of the war meant release of man power and equipment for research and field experimentation and the application of various wartime techniques, with the result that the postwar period has been one of significant advances.

The newest phases of such developments are dealt with by O. D. Donnell and A. Jacobsen in their chapter, Exploration Technology, and by John M. Lovejoy in his chapter on Production Technology.

But there is another reason why this volume is most timely. After the war, the petroleum industry was faced with a pent-up demand for products that exceeded anything ever before encountered, even the tremendous war demand. It was under the necessity of launching, which it did, the greatest program of investment in plant and facilities ever undertaken. Mainly owing to shortage of steel, by which all industries were affected during the period, to transportation bottlenecks, and to the ill luck of a particularly severe winter in 1947–1948, the oil industry was subjected to the hue and cry of "oil shortage" and threatened with every manner of government regulation and control. No actual oil shortage took place. That the public is left somewhat confused is not surprising. The editor believes this volume will do much to remove such confusion.

In his chapter, The Role of Private Enterprise in the Development of Oil Resources, Mr. Hallanan sees the American oil industry as the exemplification of the advantages of free private enterprise. Oil has been called a product of freedom. It is not found—it must be won from the earth. The history of petroleum over the world and the preeminence of the United States and the important part Americans have played in developing oil reserves both at home and abroad, as revealed in the chapters of this book, show that initiative and enterprise, with the spur of competition, are the real tools by which it is won.

It is as impossible to divorce the role of private enterprise from the subject of our oil resources as it would be to ignore the part played by the driller, the geologist, the technologist. Therefore, the editor has included the statement of principles entitled, A National Oil Policy for the United States, promulgated by the National Petroleum Council.

Oil and natural-gas reserve estimates of the American Petroleum Institute and the American Gas Association are given.

With special reference to resources and the recent so-called oil shortage, there are included in this volume a paper by L. F. McCollum discussing the American Petroleum Institute Committee's Long-term Reserves Report, together with the text of the report itself, and also Dr. Robert E. Wilson's paper, How the Oil-supply Problem Was Licked.

Included in this volume is a comprehensive study entitled A Case History of Oil-shortage Scares. It gives a documented account of all oil-shortage scares since 1913–1914. It shows how the oil industry, given free play, has *always found the oil.* This study should prove important as a reference source for students, economists, and others.

Because of the recent and growing interest in synthetic liquid fuels from coal, shale, natural gas, and other nonpetroleum sources, the new chapter, Our Supplemental Petroleum Reserves, by Eugene Ayres, assumes unusual importance. A chapter is also devoted to The Bureau of Mines Demonstration Plants in the Synthetic-fuels Picture.

Eugene Holman has brought down to date his important and timely chapter, American Oil Companies in Foreign Petroleum Operations.

In his section, The Earth's Petroleum Resources, Wallace E. Pratt gives a most complete picture of the reserves potentialities of the Continental Shelf, another matter of timely importance in connection with the tidelands problem.

Credits for photographs and illustrations go to: in Chap. III, the Arabian-American Oil Company, Gulf Oil Corporation, and Standard Oil Company (New Jersey); in Chap. IV, the American Petroleum Institute and Gulf Oil Corporation; in Chap. V, the American Petroleum Institute; and in Chap. VIII, the U.S. Bureau of Mines.

To all who have so generously contributed of their time and effort to this undertaking, the editor wishes to express his sincere appreciation.

LEONARD M. FANNING

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February, 1950

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Chapter I

THE ROLE OF PRIVATE ENTERPRISE IN THE DEVELOPMENT OF OIL RESOURCES

By Walter S. Hallanan

President, Plymouth Oil Company, and Chairman, National Petroleum Council

The one single factor which has made America the richest and most powerful nation on earth has been its system of free competitive enterprise.

It was this spirit which, unhampered by unnecessary governmental control or restriction during the first 150 years of the life of this republic, furnished the spark that transformed a trackless wilderness into a populous land of productivity, plenty, and prosperity. Stifled by monarchial governments elsewhere in the world, this spirit found free expression in the new land of liberty, and it has been reflected in a dynamic economy that has provided the highest living standards ever enjoyed by any people at any place and at any time within the recorded history of mankind.

Because of the very great and unusual hazards involved, the petroleum industry has been the outstanding symbol of this spirit of daring and adventure. As a consequence, the responsibility for maintenance of the freedom we have enjoyed in this nation rests more heavily upon the oil industry than upon any other segment of our economy.

The experience of those who have engaged in the discovery and development of our oil resources and in their processing and distribution has demonstrated that only the free are strong and that only the strong can be free. There has been no place in this romantic American adventure for the laggards or weaklings. The disappointments encountered in the search for oil and the serious problems presented by its development call for the highest degree of ingenuity and courage.

The petroleum industry is only ninety years old. This is a very brief period in the life of a civilization. Many persons are still living who were upon the earth when the Drake well was drilled at Titusville, Pa., in 1859. This epochal discovery took America out of the candlelight and ushered in the kerosene age. Some decades later, the internal-combustion engine came along to give mobility to America and to accelerate the expansion of its economy at a pace that had never been dreamed of.

This development imposed gigantic and ever-increasing demands upon the oil industry. Our vast system of highways is choked today with passenger cars, trucks, and busses; the sky is filled with airplanes, all a part of our modern system of transportation which brings 140 million people close together in their daily lives and pursuits. This could not have been realized if the oil industry had failed to develop the oil reserves of the nation so necessary to meet the demands of a new era and a higher civilization.

These enormous demands could not have been supplied by individual effort. If we had clung to the methods of the kerosene age, America would have been stalled on dead center. As our economy expanded and the demands of this new era reached astronomical proportions, it became necessary for individuals to integrate their capital and their efforts. In short, the needs of the people became so enormous in our dynamic economy that only giants could do the job of meeting those needs.

These so-called giants of achievement are called "corporations." While some political demagogues point the finger of scorn at these manifestations of collective effort, they conveniently overlook that these corporations are nothing more or less than collections of individuals. More important, these political ax grinders choose to ignore the fact that only through the efforts of such large business organizations could the demands of the American people be satisfied.

Mass production has made it possible for the American people to enjoy the luxuries of life which no other people know. It has made possible the closest approach to the abolition of poverty. It has reduced the cost of many modern essentials of life to bring them within the reach of every home.

There are many persons in and out of public life who contend that bigness constitutes evil in itself. This has become a fertile field for the political demagogues. They level indiscriminate attacks upon all big business, irrespective of its necessity and of its service. These men pose as "liberals," although they are the real reactionaries, whose doctrine would put the brakes on the progress and development of our country. They would take us back to the economic Middle Ages. But we of the oil industry do not believe America is going backward. We believe it is going forward to conquer new frontiers and scale new heights of achievement.

American corporations have grown big because there were big jobs to be done. If the multitude of persons, each of limited resources, who are the stockholders in these corporations had not integrated their assets and talents, these jobs could not have been done and the American people would have been denied the high living standards which they enjoy.

Just as it became necessary for individuals and small business operations to integrate their resources and facilities in order to keep pace with the demands of a surging and seething economy, it was of vital importance, in the public interest, for oil companies to integrate their facilities into a smooth, economical, and efficient over-all organization. Integration is the one essential factor that has made it possible for the oil industry to meet every demand of the American people both in peace and in war. Its continuation and expansion within the framework of our statutory requirements should be encouraged as a measure of greater public service and in the protection of our national security.

Those who condemn integrated business activities and use the powers of government for their dissolution render a very great disservice to the American people. It was such integrated industrial operations that have saved this country in time of war and served it well in time of peace. Great organizations of capital, man power, and technical skill produced the instruments of war in incredible amounts and with equally incredible speed. So far as petroleum is concerned, it is the proud boast of our industry that not once during the Second World War was a single American airplane, tank, warship, or other facility of war immobilized because of a lack of petroleum. The industry did that job, just as it has been meeting the challenge of greater peacetime demands, because all of its many separate phases were organized into a harmonious operation.

It should be made crystal clear that there is always a place in the oil industry and throughout American business for the small operator. He is just as vital to the maintenance and expansion of our high level of productivity and distribution as are the large integrated structures. It is the function of government to protect him from unfair and destructive competition. It is *not* a governmental function to destroy big organizations of business just because they are big and integrated. Such organizations are entitled to the same protection and encouragement, in their fair and legitimate operation, as the small operator.

In the oil business, we know that it has been the so-called "one-gallus" operator who has been the backbone of the industry's development. There are thousands of these individuals, partnerships, and small corporations in the business today, largely in the production and distribution departments. They provide a necessary supplement to the work of the integrated companies, which, in turn, supplement the endeavors of the independents. One could not survive without the other. Each is dependent upon the other.

It is a matter of record that approximately 75 per cent of our petroleum reserves have been discovered by individuals and small independent companies. Distribution of petroleum products is almost entirely in the hands of individuals and independent companies.

The false and insidious propaganda of the advocates of the socialized state has sought to convince the public that the oil business is a monopoly, with ownership of all its facilities vested in a handful of major integrated companies. This propaganda has been put out over the radio, through the press, in speeches by political demagogues, and in at least one book recently written by an eminent professor of a leading university.

The facts are that there are more than 34,000 companies in the oil business in the United States, or an average of 1 company for every 4,000 persons in this country. Of these, 13,475 are engaged in production, 400 are in the refining business, 650 are engaged in the transportation of petroleum and its products, and 20,000 deal with marketing and distribution. There are almost 250,000 service stations in the United States, and 19 out of 20 of them are independently owned or leased. There are also tens of thousands of other retail outlets for oil and oil products.

This gigantic combined effort of these thousands of individuals and small business operations and the few large integrated structures is one of the finest examples of free competitive enterprise.

As a result of this competition, better petroleum products in adequate quantities are made available to the consuming public at reasonable prices. Those are the facts, and they furnish an annihilating answer to those who, with sinister purpose, have propagated the idea that the oil industry is an enormous monopoly.

Whenever and wherever there has been a real job to be done, either in peace or in war, the oil industry has come forth with the men who had the "know-how" to do that job. The reason those men have been available is because our industry has been permitted to work in a political climate that encouraged initiative and rewarded success. It has established such an unparalleled record through the joint efforts of its large integrated companies and the thousands of individual, partnership, and small corporate enterprises, working together in a common cause for the public good.

America has little to fear from its business giants, who have served the country so well, as compared with the very real and imminent peril that it faces from the giant of government. In pointing out this danger, I should like to quote from an address delivered in the United States Senate by a far-seeing American. The distinguished speaker said:

"I do not dread these corporations as instruments of power to destroy this country, because there are a thousand agencies which can regulate, restrain, and control them, but there is a corporation we may all dread. That corporation is the Federal government. From the aggression of this corporation there can be no safety, if it is allowed to go beyond the bounds, the well-defined limits of its power. I dread nothing so much as the exercise of ungranted and doubtful powers by this government. It is, in my opinion, the danger of dangers to the future of this country."

That speech was delivered seventy-one years ago, on Mar. 27, 1878, by Senator Benjamin Hill. We may wonder what Senator Hill would think, if he were alive today and saw a government that already owns one-fourth of all the land in continental United States; a government that is the largest employer in the world with more than 2 million civilian employees receiving salaries totaling 6 billion dollars a year; a government that provides benefits, subsidies, and handouts to millions of others in such abundance that one out of every six adult Americans receives some form of government payment regularly from Washington.

That same government has proposed—in administration bills placed before the Congress—that it be given power to fix prices, regulate production, go into any kind of business, select your doctors and dentists, and take a long step in the direction of control over our free educational institutions. This reactionary philosophy is based upon the assumption that the American people are too stupid to manage their own affairs; that they are, as one powerful governmental leader expressed it, "too damn dumb to understand."

The oil industry completely and utterly rejects the philosophy that the American people—the best educated people on earth—are incompetent to handle their own affairs and carve out their own destinies under the will and conscience given to them by the Almighty. They have done a pretty good job so far, and they are willing to match their record against that of any government-controlled economy in the world.

The time has come to give full answer to the communists and the demagogues who picture the American business system as one of Shylocks without conscience or sense of public responsibility. We can make up our minds that, if we do not fight to maintain our national integrity, we will see our country go the way of all nations which have embraced the socialistic state in any form.

If we do not have the courage of our convictions, if we do not have faith in our system, then we do not deserve to remain free. But we do have that courage. We do have that faith. With divine help, we shall meet the crisis facing us today and solve it. Let us resolve together that our republic, founded in faith, conscience, compassion, and law, shall continue in freedom, in dignity, and in peace.

Chapter II

A NATIONAL OIL POLICY FOR THE UNITED STATES

Formulated by THE NATIONAL PETROLEUM COUNCIL *at the Request of the Secretary of the Interior*[1]

INTRODUCTION

An adequate supply of oil is essential to the American standard of living. Oil in increasing quantities will be required in the future to meet the needs of our expanding economy. A prime weapon of victory in two world wars, it is a bulwark of our national security.

Favorable conditions have existed for the growth of the American oil industry—conditions which have made possible its achievements and its many contributions to the nation. The methods and procedures and the regulations and laws relating to oil which have evolved over the years have constituted a national oil policy, the success of which would indicate that its key elements should continue to guide us.

The industry has expressed its position on past occasions. It would now seem in the public interest that the principles of a sound national oil policy should be reappraised and restated. The National Petroleum Council, by virtue of its broad representation, the experience of its members in the oil industry, its realization of the great importance of oil and natural gas, and its deep interest in the welfare and security of this country, is pleased to respond to the request of the Secretary of the Interior and present its views as to the aims and essentials of such a policy.

THE AIMS OF A NATIONAL OIL POLICY

To be effective, a national oil policy should have the following objectives:

1. It should result in a maximum contribution by the oil industry to an expanding American economy and to a rising standard of living, including stable employment at fair wages within the industry.

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[1] Presented Jan. 13, 1949. See Appendix *A*.

2. It should maintain conditions most likely to assure adequate supplies of petroleum in both peace and war.

3. It should maintain conditions, within the free-enterprise system, most likely to assure adequate supplies of essential materials equitably available to all units in the industry in both peace and war.

4. It should contribute to the expansion of trade and of industrial activity at home and abroad by encouraging American nationals in the development of both domestic and foreign oil resources.

5. It should operate to strengthen our free institutions by demonstrating that the issues which periodically arise in an industrial democracy, involving the relations of government and private industry, of state and individual, can be successfully resolved within our existing institutional framework.

To attain these ends, a national oil policy should establish the broad terms under which there will be sufficient flexibility to meet new conditions resulting from technological progress, economic change, and the possible requirements of national emergencies.

The oil industry has been progressive in its support and application of scientific research and in its readiness to meet new demands. A national oil policy must anticipate and provide for the certainty that further progress will create new problems. It should encourage flexibility in the functioning of the industry itself and continued adaptability to new circumstances in time of peace or crisis, which is one of its outstanding characteristics.

Fundamental Principles

The following general principles are fundamental to a sound national oil policy:

1. The national security and welfare require a healthy domestic oil industry.

Continuing supply to meet our national oil needs depends primarily on availability from domestic sources. Due consideration should be given to the development of foreign oil resources, but the paramount objective should be to maintain conditions best suited to a healthy domestic industry, which is essential to national security and welfare. To this end, adequate and equitable availability of essential materials is a fundamental requisite.

2. The public interest can best be served by a vigorous, competi-

tive oil industry operating under the incentives of private enterprise.

The very nature of oil is such that multiple efforts on a very wide scale and initiative in high degree are required in all phases of industry operations from finding to distribution.

The participation by many in the far-flung and diverse activities of the industry provides those multiple sources of initiative, imagination, and responsibility, out of which spring a great variety of discoveries and inventions, new ideas, and tremendous productivity.

The competitive form of economic organization, by offering the promise of reward commensurate with contribution and efficiency, utilizes a motivating force for which no adequate substitute has been found. Other nations have tried other methods, but it is the American oil industry operating under the American system which sets the highest standards of achievement and service.

3. The appropriate functions of Federal and state governments in relation to the industry and the principles underlying their present relationships should be maintained.

Under the concepts of the American economy the functions of government with respect to industry are primarily to provide the conditions under which industry may operate with maximum efficiency and to assure that the public interest is safeguarded.

The functions of the oil industry are to discover, produce, and transport oil and to refine and distribute its products. Participation in such operations is not a proper function of government.

In the exercise of their powers a clear line of demarcation should continue to exist between Federal and state governments.

The operation of the American petroleum industry is grounded on state regulations of oil and gas production in the interest of conservation. State regulation under our constitutional system evolved as the legal and most effective answer to the problem of a widely dispersed natural resource. State authorities have proved effective in their protection of the public welfare, and the decentralized approach has been highly successful in meeting the wide variety of conditions that prevail in different areas.

When oil-conservation problems have arisen involving coordination among states, instrumentalities have been developed to deal with them effectively, such as the Interstate Oil Compact to Conserve Oil and Gas, operating with the sanction and aid of the Federal government.

4. No government actions specifically affecting the oil industry should be taken without proper regard for the long-term effect and without consultation with the industry.

Mainly because of restrictions brought about by the war, temporary difficulties developed in supplying the sharply increased postwar demand. Some, in both public and governmental circles, gained the false impression that this country was faced with a permanent oil shortage requiring special measures.

Situations of this kind invite the consideration of dangerous expedients. Such measures directed at a single, passing phase of a cycle are not only unnecessary but can be destructive of sound long-range policy.

The oil economy is acutely sensitive to governmental interferences with the free market. As long as a free market prevails, price functions effectively as a regulator of supply and demand and as an allocator of supply to the channels of greatest need. It also provides the necessary incentives for exploration, increased efficiency, and technological improvement and permits the capital formation necessary to continued progress.

These conditions assure a vigorous industry prepared to meet a real emergency if it arises. In the two world wars, the industry's readiness was a decisive factor in our victories.

The Elements of a National Oil Policy

The general principles which have been outlined constitute the broad base of a sound national oil policy. In the formulation of that policy consideration should be given to a number of elements, which are outlined herewith under five headings, Domestic Oil, Natural Gas, Foreign Oil, Imports, and National Security.

I. DOMESTIC OIL

1. The key industry function of oil exploration and discovery presents extraordinary difficulties and risks. It is best promoted by competitive effort and by the incentive of commensurate reward.

Undiscovered oil is a present asset to no one.

The natural petroleum potentialities of the United States are very large, and oil exists outside the United States in great abundance. When conditions justify, these natural supplies can be supplemented by the vast resources available through synthesis of coal, shale, and natural gas. There will be liquid fuels enough for many generations to come.

Details of policy relating to production, refining, distribution, and utilization of oil become academic, however, unless provision is made to assure that this oil will be found and brought to the surface. The promotion of new discoveries, therefore, must be the primary consideration of national policy. This involves continuing encouragement of private exploration efforts at home and abroad, so that ample sources of oil will be under development at all times for peace or emergency needs.

Finding oil calls for the efforts of a great many people of different characteristics. Despite the development of scientific methods, a major factor in discovery is still the willingness of many individuals and competing industry units, exercising independent judgments, to take risks. The chances of finding oil are increased as more people are encouraged to accumulate and venture their capital on their own initiative.

Many government policies have a bearing on exploration efforts, including actions with respect to public lands, tidelands, and tax provisions. These policies should operate to accelerate and not retard exploration.

2. Conservation of our petroleum resources will best be furthered by facilitating continued industry efforts to reduce waste and promote maximum recovery of oil through optimum-rate production, unit operation, secondary recovery, and other methods.

True conservation of our oil resources cannot be achieved by hoarding them in idleness. It is only by active development that the earth's potential wealth is converted into real wealth useful to man. The resulting gain is not only in products. Through the exercise of its human resources society acquires skilled workers and technicians and a vast storehouse of knowledge with which to make further progress.

Optimum-rate Production. Over the past twenty years the industry has developed engineering methods designed to eliminate waste and to increase the recovery from oil fields. This procedure is based on the discovery that the total recovery is greatly augmented when the flow from oil wells is not permitted to exceed maximum efficient rates. Most of the information on which maximum efficient rates are determined has been developed through industry research on the nature of oil-bearing structures and underground movements of oil.

The economic operations of oil fields within the limits of maximum efficient rates are referred to as "optimum-rate production." The public interest and the private interests of oil operators are equally served by the application of this principle. On the one hand, it assures the consumer of a greater supply of fuel in the long run, and on the other it enables the producer to obtain the maximum yield from his properties.

The system of optimum-rate production has been very effectively developed in those states having conservation statutes. Efficient production rates are periodically fixed and revised after public hearings by state regulatory bodies upon the basis of engineering studies and actual operating conditions. Support and extension of this system by the states should be encouraged.

Unit Operation. In oil fields in which more than one operator have interests and where unit operation would result in greater ultimate recovery, appropriate action should be taken by the states to encourage such operations.

The establishment and operation of unitized pools, which satisfactorily protect the correlative rights of the various operators and royalty owners against the improper and inequitable drainage of their respective reserves by adjacent operators, should be favored. Considerable progress in this direction has been made by voluntary unitization and cooperative agreements.

Where legal obstacles to such arrangements exist, the state laws should be clarified to encourage voluntary cooperative unit plans.

The development of our oil resources can be further encouraged by clarifying Federal tax laws with respect to unit operations. Voluntary unit operation of a single reservoir by several operators is clearly in the interest of conservation. Such undertakings should not be taxed as separate business entities, because the effect would be double taxation. The elimination of uncertainties on this score will give further impetus to oil and gas conservation.

Secondary Recovery. Vast amounts of oil still remain in so-called "depleted" fields which were developed and produced before modern methods of optimum-rate production became general.

The industry has developed scientific and economic methods of secondary recovery which provide the means of adding vast quantities of oil to our recoverable reserves. Continued research and improvement in techniques are desirable.

Utilization. The efficient utilization of oil products by fuel-burning mechanisms of all kinds and in other applications is important to conservation. The oil industry should continue to cooperate with other industries in seeking the maximum development of oil-saving improvements.

3. Technology is a creative force of major importance in expanding our petroleum resources and in providing adequate supplies of oil at reasonable prices. The competitive conditions under which the industry's great technological advances have been made should be maintained.

The oil industry is a conspicuous example of the extraordinary achievements of American research and technology. In all phases of the petroleum industry they have operated to multiply our resources and lessen costs to the consumer.

Scientific advances in exploration have augmented our ability to locate oil fields. Technology and engineering have increased the quantity of oil which can be recovered from new and old fields. Research has improved the efficiency of refining processes, increasing flexibility in yield and quality and diversity of products. Losses in oil handling and transportation have been greatly reduced. Continual improvements in oil-burning devices of all kinds have the net effect of increasing the quantity of oil available for future use.

Computing barrels of recoverable oil in proven fields is not an adequate measure of the ultimate volume of oil or oil products obtainable. Calculations made in one period are likely to be invalidated later by advances in production, refining, or utilization techniques. In the period between the First World War and the Second World War, research was a major factor in the multiplication of reserves and in the industry's ability to produce aviation fuels, special lubricants, synthetic rubber, toluol, and many other products.

Science and technology can flourish only in a society in which there are intellectual freedom and freedom of expression. Our competitive economy not only provides these conditions, but it stimulates the best efforts of thousands of individuals to pursue independent paths of inquiry unhampered by centralized control.

In the United States, both private and public agencies have provided unexampled research facilities. To the unrestricted individual pursuit of knowledge, American organizational genius has added another factor—the coordination of research, engineering, and development within a company—which reduces duplication of effort and speeds the solution of problems by directed teamwork of scientific workers

Our patent laws have also played a vital part in encouraging technological progress. They are based on the fundamental principle of disclosure. By offering exclusive rights for a limited time, our patent system provides inducements for the prompt disclosure of new advances and discoveries which, when known to others, become in turn the foundation for new improvements.

4. The economic and efficient development of synthetic fuels to supplement natural petroleum as needed can best be achieved by private industry.

The oil industry through extensive research has provided the technological basis on which a synthetic-fuel industry can be established when conditions require. The furtherance of research and process development by the industry is desirable. Research by governmental agencies should be limited to fundamental studies and to surveys of raw-material reserves. The construction of synthetic-fuel plants by government intervention would defeat the objectives of an adequate oil supply by impeding the normal functioning of the industry. Synthetic fuels will attain an orderly and economic development by private industry, if normal incentives are free to operate.

5. Oil and gas are only a part of our nation's energy resources. All these resources combined are adequate to meet energy needs; the relative use of each will be determined most effectively by the operation of price in a free market.

A continuance of favorable conditions for private competitive enterprise will provide American consumers with sufficient energy and power for an expanding economy. There are ample energy resources—coal, crude oil, gas, and water power—to meet our needs for a long time; and price adjustments will regulate the relative use of these resources so that over an extended period the demand and supply of each will be balanced. Present technology makes it possible to convert coal and gas into liquid fuels, thereby appropriately supplementing petroleum for the uses in which liquid fuels are superior. The degree to which this conversion will take place will best be determined by economic considerations which include consumers' evaluation of the relative convenience of liquid fuels.

6. The provisions in tax laws which have long recognized the

requirements of petroleum operations are essential to the continued development of our oil resources and, in furtherance of the public interest, should be maintained.

The industry's ability to carry on an intensive and long-range search for new oil and gas fields has been greatly facilitated by Federal tax provisions for depletion and for deductions of intangible drilling, geophysical, and geological expenditures.

These provisions help provide the capital necessary for exploration. With the nation's demand for oil increasing, multiple efforts in oil finding should be stimulated to the fullest possible extent.

7. The petroleum resources of the lands beneath the marginal seas extending to the outer edge of the Continental Shelf can best be explored and developed under state, rather than Federal, control.

Substantial quantities of oil lie under the seas bordering the shores of several states. They constitute one of the most important sources of additional domestic oil supply remaining to be discovered and developed. A prudent oil policy would require that these resources be discovered and developed as soon as possible.

Years of experience have demonstrated that state laws and regulations, designed to provide the necessary incentives and proper conservation practices, and on-the-ground state administration encourage the risk taking vital to the discovery and development of petroleum resources. Federal laws and regulations, with final authority far removed from the scene of operations, have tended to discourage exploration for oil underlying Federal lands and to retard its discovery.

Furthermore, on historic and constitutional grounds and under judicial precedents, the abutting states should own the lands and the resources beneath the marginal sea to the outer edge of the Continental Shelf inasmuch as any area within or appurtenant to the continental United States is required, under our Federal system, to be included in one or more states of the Union. A sound national policy should prompt Congress to confirm in such abutting states the ownership of the lands and subsoil beneath such marginal seas.

8. Continued industry efforts to find and develop oil and gas on Federal public lands should be encouraged.

The policy of leasing the public domain for oil and gas exploration can contribute importantly to the efficient development of the nation's oil resources.

The statutes, rules, and regulations which govern these operations have in many instances retarded full development. They should be reviewed with the objective of stimulating further development. Points of improvement include the more expeditious leasing of the lands, the relaxation of acreage restrictions, and the issuance of leases which give management control to the lessee.

9. Conditions should be maintained under which the industry may continue to form the capital required to expand its operations to meet the nation's growing needs for petroleum.

All segments of the oil industry continually require capital to replace obsolete equipment and to expand their facilities and operations. These requirements are increasing as the population grows and the American standard of living is raised to higher levels. The bulk of the capital the industry employs has been created by the industry out of its own operations. Its future needs can best be met under a system of free markets and suitable tax provisions.

In addition, it is important that conditions be such as to encourage the thousands of small operators who are indispensable to a vigorous industry. When all segments of the industry are able to function in an atmosphere of confidence and stability, the extension of credits is facilitated and they are assured of sufficient capital to operate successfully.

10. Efficient marketing of oil and oil products is a major responsibility of the industry. It should continue to support and encourage a system of distribution under which thousands of independent marketers, integrated companies, and others compete to bring the industry's products to the consumer.

The oil distributor—both wholesaler and retailer—is the channel through which the industry serves the ultimate consumer.

Most oil distributors are independent businessmen who buy at wholesale. The marketing of petroleum is particularly suited to operations by individuals and small units, and the industry considers that the public interest will be served by continuing to encourage the existing competitive system.

The industry fully recognizes the interdependence of all units in the industry, large and small. It is important to the public and to the industry that the distribution system should be efficient, so that the benefits of progress in all branches of the industry will be passed on to the consumer.

Marketers should be encouraged to increase their service to the public through continued improvement in distribution methods, the opening of new facilities where needed, the introduction of new products, added conveniences, and courteous treatment.

The industry believes that competition for consumer preference is the best way to assure such service.

11. The oil industry is opposed to monopoly and believes that competition contributes to the public good.

The oil industry should operate on a basis which will contribute to the economic progress of the American people and provide needed supplies of oil. This objective requires an adequate productive effort and stable employment of hundreds of thousands of workers. It involves continued technological advance, elimination of waste, and avoidance of violent changes in output and employment.

The industry structure, which consists of many large and small enterprises and operations, has demonstrated its effectiveness under a competitive system which assures the attainment of these objectives.

The industry subscribes to the fundamental principles underlying the antitrust laws. It recognizes a continuing responsibility to maintain the rivalry in price, quality, and service which promotes technical progress and efficiency and passes on these benefits to the public.

II. NATURAL GAS

1. State and Federal laws should encourage, not impede, the development of natural-gas resources by industry.

Natural gas is closely associated with oil, and the production of both frequently coincides. Natural gas is assuming an increasingly important role as an energy source, not only for heating but in industrial processes and as a future source of synthetic liquid fuels. It is in the public interest, therefore, that the conservation, efficient production, and use of natural gas should be fostered.

The several states should encourage by appropriate legislation arrangements among producers for the installation and operation of cycling and repressuring projects and other operating means for fostering the conservation and utilization of gas in and from oil and gas reservoirs.

The quantities of natural gas produced by many gas-producing states are in excess of the consumption of gas within those states. It is important, therefore, that the producers of gas have full opportunity to sell gas to interstate carriers for resale by them to local gas-distributing companies. Interstate transportation of natural gas and its sale in interstate commerce for resale are under Federal regulation. A threat exists that Federal regulation will be extended to include control over the production and gathering of gas and the price charged by producers and gatherers. This threat has the effect of discouraging the maximum development of facilities for gas utilization and the production and sale of gas in interstate commerce.

The proper sphere of regulation by Federal agencies is interstate commerce. Such agencies should have no authority to control directly or indirectly the production, gathering, and processing of gas or its price at or prior to its delivery into the main line of an interstate carrier or to control the local distribution of gas. In carrying out their proper function of regulating the transportation of natural gas in interstate commerce, Federal regulatory bodies should apply a formula which would allow an interstate carrier of natural gas to charge for gas delivered through its facilities a price which includes the price paid for the gas it purchased and the market value of the gas it produced.

End-use Control. It is not the function of the Federal government to control the end use of gas any more than it is its function to control the end use of coal, crude oil, cotton, wheat, or other commodities. The Constitution does not confer upon the Congress the power to control end use, and the exercise of such authority would be contrary to American principles. Control over the end use of gas would require control over the end use of other energy resources, which would lead to a vast bureaucracy involving a regimented industry and managed economy.

Gas is in open competition with coal, crude oil, and water power, the other energy resources. In a free economy, competition is the best regulator of the end use of gas. If Federal or state authority is extended into this area, private incentives would be restricted and development of the gas industry would be retarded. Furthermore, pressure groups would be encouraged to seek to establish standards or restrictions for their special advantage.

III. FOREIGN OIL

1. The participation of United States nationals in the development of world oil resources is in the interest of all nations and essential to our national security.

The importance of oil to economic and social progress is not confined to the United States. All nations need more oil for industrial development and to raise living standards.

Oil exists in many places in the world. Its efficient production is important both to the country where it is produced and to the world economy. The oil which a nation does not need for its own uses should find its way through the channels of international trade to other countries.

Oil from abroad should be available to the United States to the extent that it may be needed to supplement our domestic supplies. The availability of oil outside of the United States, in places well situated to supply our offshore requirements in time of emergency, is of importance to our national security.

Oil technology has been more highly developed by the United States than by any other nation. American methods and skills have made great contributions to the discovery, development, and conservation of oil resources in other countries. American interests today participate widely in international oil development. Conditions should be fostered that will further this participation but not to the extent that this involves preferential treatment of operations abroad at the expense of the domestic industry.

2. An effective oil policy should encourage access by our nationals to world oil resources on equal terms with other nationals and stable agreements between foreign governments and private industry on a basis which will promote development by free-enterprise methods.

A country's oil resources are best developed when all who are engaged in petroleum operations—its own nationals and those of foreign nations—compete on equal terms. Favored treatment of one group at the expense of another, state monopolies, and state competition in any phase of oil retard maximum development and are not in a nation's long-run interest.

The government of each country and its nationals should respect all valid concession contracts and lawfully acquired rights and should make no unilateral effort to interfere directly or indirectly with such contracts or rights.

Agreements between foreign governments and private enterprise should define the proper functions of each. They should provide to the companies operating in those countries security of title to the property or rights acquired; managerial control of operations; the opportunity to make a reasonable profit commensurate with the risks originally assumed and to form capital for expansion; and means for the prompt and fair settlement of disputes that may arise.

Foreign governments in return have a right to expect to participate in the benefits from ventures on their soil. Such participation includes payments of reasonable royalties and taxes. It is also reasonable that foreign countries should expect that their own requirements for oil be satisfied before any oil is exported, that waste be avoided, and that their people receive training and employment at fair wages.

3. The Federal government should encourage foreign oil development by American nationals by efforts directed through diplomatic channels to reduce political risks involved in such foreign operations and by permitting United States citizens to operate abroad in conformity with the laws and customs of other countries.

It is in the national interest that American oil companies should continue to take an active part in the development of petroleum resources in other countries.

The Federal government, therefore, by diplomatic representations, should exert its influence in behalf of a sound oil policy. It should seek to assure the observance of agreements made between foreign governments and American nationals and to minimize the political risks involved in foreign operations.

If American firms are to do business abroad, they must conform to the laws and customs of the countries in which they operate. American companies should not be penalized on occasions when such requirements conflict with the rules laid down for the conduct of business within this country, as long as these operations are consistent with the interests of the United States.

IV. IMPORTS

1. The nation's economic welfare and security require a policy on petroleum imports which will encourage exploration and de-

velopment efforts in the domestic industry and which will make available a maximum supply of domestic oil to meet the needs of this nation.

The availability of petroleum from domestic fields produced under sound conservation practices, together with other pertinent factors, provides the means for determining if imports are necessary and the extent to which imports are desirable to supplement our oil supplies on a basis which will be sound in terms of the national economy and in terms of conservation.

The implementation of an import policy, therefore, should be flexible so that adjustments may readily be made from time to time.

Imports in excess of our economic needs, after taking into account domestic production in conformance with good conservation practices and within the limits of maximum efficient rates of production, will retard domestic exploration and development of new oil fields and the technological progress in all branches of the industry which is essential to the nation's economic welfare and security.

V. NATIONAL SECURITY

1. The maintenance of a vigorous oil industry in time of peace is the best way to assure the reserves and facilities needed in time of war.

The normal operations of the oil industry, under which oil is produced at optimum rates, provide the United States and other countries with a continuing reserve of potential productive capacity. In the event of a protracted national emergency, during which essential petroleum requirements might increase rapidly, this reserve productive capacity could be drawn upon to satisfy peak demands.

Civilian rationing of oil would be necessary under a war economy, as it would be for most commodities which are needed in large quantities by the armed services. Rationing would provide a large surplus of oil during the early stages of a conflict. Other measures could then be instituted as circumstances dictated. If storage facilities were provided, military stock piles could readily be accumulated out of the surplus to meet such sharply rising requirements as the armed services might anticipate with a mounting pace of operations. In the meantime, reserve productive capacity could be maintained through the continuation or expansion of exploratory efforts. If the need for additional quantities is anticipated, supplemental volumes could be obtained through synthesis of natural gas, oil shales, and coal, for which we have the necessary technological information, although very large requirements of steel and man power would be necessary.

It is clearly in the interests of national security that peacetime conditions which encourage the development of available reserves by private industry should be promoted. An active program of exploration by the industry is essential. High peacetime requirements for oil create high reserve productive capacity. They result, furthermore, in the competitive development of refining, transportation, and other facilities. The greater the civilian consumption at the outset of a war, the larger will be the supplies available through rationing.

Withholding from development the oil on public lands or in offshore areas, with the thought that it can be used in an emergency, is not sound policy in terms of national security This oil can be made fully available only by continuous and prolonged peacetime development.

The "locking up" of proved reserves by arbitrarily curtailing existing production or by acquiring proven oil fields through purchase or condemnation is unnecessary and would retard the normal development of the industry. Importing oil and storing it in depleted or partly depleted oil or gas fields in the United States is also unnecessary as well as impractical.

A large expansion of reserves can be attained by the active development of foreign sources of supply, particularly those tributary to offshore requirement areas.

2. The government should accumulate such inventories of petroleum products in peacetime as would be needed by the armed services in the early stages of a conflict.

Stock accumulation by the government is desirable to the extent that adequate supplies of products of military specification may be assured for the initial period of a conflict. Stocks of such products should be stored in sufficient quantity to last until conversion of industry facilities or construction of additional facilities can be completed.

Special provision should be made for storing products such as aviation alkylates, which cannot be obtained by simple substitution or process change from civilian products, and products such as tetraethyl lead, for the production of which only a limited number of units now exist.

Stock piling on a massive scale in peacetime is unnecessary and impractical. If required, petroleum supplies could be accumulated through rationing during the early period of an emergency which, with additional supplies available through increased production and continued rationing, should be sufficient to meet the requirements of such an emergency.

3. Procedures for government-industry consultation should be maintained on a permanent basis so that plans to meet emergencies can be adjusted continually to changing conditions.

The problems of national security with respect to petroleum involve problems relating to our entire economy. They encompass not only military and civilian needs for oil but questions of supply of other commodities which affect the supply of petroleum.

It is impossible at this time to evaluate, except in general terms, the problems of an unknown future. Attempts to anticipate all the needs of protracted war would tend to establish rigid patterns which could seriously affect the economy and strength of the nation. Wise policies and appropriate actions must evolve out of constant study of changing factors.

The soundest procedure is to direct studies principally to the immediate and short-term requirements of an emergency. The existing Military Petroleum Advisory Board should continue to function. Among the problems for consideration are the time required to expand military supplies and contract civilian consumption; the rapidity of increase in requirements of particular military products in relation to expansion of special facilities to produce them; the interrelationship of production, refining, and transportation facilities under initial war conditions; the relative vulnerability of facilities for the production of particular products; the wartime availability of materials and manpower required to sustain or increase production; and plans for providing storage capacity to accumulate military stock piles during the early period of a war.

Provisions to deal with these problems can be worked out in advance after careful study of alternatives so that unnecessary or uneconomic actions will be avoided.

In the event of another war, the experience of the Second World War will provide a basis for its successful prosecution. The pattern of government-industry cooperation through the Petroleum Administration for War and the Petroleum Industry War Council is suggested. An oil industry which has continued to progress under a sound national oil policy would again be prepared to throw all its resources, facilities, and man power to the nation's defense.

CONCLUSION

The American oil industry is distinctively a product of the American way of life. For many years it has operated under one of the most effective and efficient industrial policies in our economy.

The industry will continue to produce the optimum economic and social gains inherent in the nation's petroleum resources, granted the conditions of a free economy and continued recognition of the economic laws which direct its operations.

If, in addition, the United States government through diplomatic efforts is able to reduce the political risks inherent in foreign operations, American nationals with their capital, managerial skill, and technical knowledge can be counted on for increasingly important contributions to world recovery and peace.

Vigorous oil development under competitive conditions at home and abroad is the best way to assure our national security.

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Chapter III

AMERICAN OIL COMPANIES IN FOREIGN PETROLEUM OPERATIONS

By EUGENE HOLMAN

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That the United States domestic oil industry has been preeminent in the world petroleum picture is generally known. Less widely known is the fact that American oilmen have also played a leading part in developing foreign oil supplies. Not only have they participated in large measure in the discovery of foreign oil reserves, now greater than our own, but they have also helped to produce foreign oil, transport it, refine it abroad, and market the finished products.

In view of the readjustments in foreign trade patterns since the Second World War and the growing attention which is being paid to the formulation of world trade policies (including oil policy), the time seems propitious to review the part Americans have already played in the discovery and development of foreign oil reserves. What follows is an outline of the crowded story of American oilmen abroad. It concerns primarily the geologist and the producing man, but also included is a brief review of refining, marketing, and transport activities, with some observations on the economic and social influences which have resulted. The story has never been told in its entirety and perhaps never will be, for much of it has been lost or forgotten.

The early American oilmen lost no time in starting operations abroad. They began shipping oil to foreign markets within two years after the completion in 1859 of Col. E. L. Drake's 69-ft oil well near Titusville, Pa. The latter event is generally accepted as marking the birth of the modern oil industry. The oilmen's interest in foreign countries has never lagged since then, and over the years Americans have marketed petroleum products in every corner of the world. Americans have searched for and discovered large oil reserves in most of the world's oil regions, except where barred by nationalistic laws or policies. The best measure of their success perhaps is the fact that they hold today more than two-fifths of proved foreign reserves. Further, the technical skill and advice of American technicians have been instrumental in finding and developing much of the remaining three-fifths of foreign reserves held by other nationalities.

Let us review briefly the history of developments abroad according to the major divisions of the industry. We can best look at production first, since it is the focal point of the national interest in our foreign operations and the major factor in the international diplomatic activity centering around the industry.

Crude-oil Production

The search for oil outside the United States began almost immediately after the Drake well was completed in this country. While the United States experienced far greater development in oil than any other nation, several, notably Russia, Rumania, and Burma, had become prominent sources of petroleum by 1900.

Table 1 shows the annual world oil production by countries from the beginning of the industry. It may be noted here that the potential oil-producing area abroad is far greater in extent than that in the continental United States, the latter possessing only about 12 per cent of the world's land area favorable to oil accumulation. See also Fig. 1 (page 32).

The earliest known effort by Americans to develop oil resources abroad occurred in 1883, when a small American operator secured prospecting acreage in Mexico. Two shallow wells were drilled practically over the site of what later became the huge Potrero del Llano pool but failed to strike oil. No further efforts are known to have been made until the turn of the century.

Shortly after the 1900's began the first American-owned production abroad—in Mexico. It was followed shortly thereafter by the appearance of an American operator in Rumania, where, however, oil had been produced for almost fifty years. These two areas remained the only sites of American producing activity until the First World War. By 1914 a total of 18 foreign countries were producing oil, with American participation amounting to approximately 13 per cent. The following table shows world production,

TABLE 1. WORLD CRUDE-OIL PRODUCTION, BY COUNTRIES AND YEARS, 1857 TO 1948* (Barrels of 42 U.S. gal daily)

Year	Rumania	United States	Italy	Canada	Russia	Poland	Japan and Taiwan	Germany	India	Burma†	Dutch East Indies	Peru	Mexico	Argentina	Trinidad	Egypt	British Borneo	Iran (Persia)	Venezuela	Ecuador	France
1857-1860	13	344																			
1861	47	5,791																			
1862	63	8,375	...	33																	
1863	77	7,154	...	227	112																
1864	90	5,781	...	246	178																
1865	107	6,844	5	301	184																
1866	115	9,858	3	479	227																
1867	140	9,169	3	521	329																
1868	153	9,963	...	546	240																
1869	162	11,548	...	603	553																
1870	230	14,414	...	685	559																
1871	247	14,260	...	740	452																
1872	249	17,194	...	842	505																
1873	285	27,107	...	1,000	1,301																
1874	282	29,937	3	463	1,597	411															
1875	296	24,075	3	603	1,910	433	14														
1876	303	24,955	8	852	3,609	448	19														
1877	296	36,576	8	855	4,934	466	27														
1878	299	42,184	11	855	6,578	482	49														
1879	301	54,560	8	1,575	7,564	589	63														
1880	314	71,820	5	956	8,199	626	71	25													
1881	334	75,784	3	753	9,866	786	47	79													
1882	373	83,151	5	755	12,433	904	41	159													
1883	381	64,246	5	685	16,444	1,000	55	74													
1884	577	66,168	8	683	29,522	1,115	77	126													
1885	529	59,888	5	685	38,151	1,274	82	112													
1886	460	76,891	5	1,600	49,332	838	104	203													
1887	499	77,488	3	1,441	50,323	942	79	203													
1888	598	75,443	3	1,899	62,975	1,276	101	232													
1889	816	96,339	3	1,932	67,422	1,411	145	186	258												
1890	1,049	125,547	8	2,178	78,605	1,805	142	296	323												
1891	1,337	148,746	22	2,069	94,721	1,729	145	299	521												
1892	1,620	138,019	49	2,131	97,746	1,765	189	276	661												
1893	1,466	132,688	52	2,186	110,841	1,899	290	274	819	......	1,644										
1894	1,392	135,188	58	2,271	99,658	2,600	474	337	896	......	1,885										
1895	1,578	144,909	71	1,980	126,411	3,981	466	332	1,019	......	3,332										
1896	1,484	166,557	49	1,986	129,019	6,678	648	396	1,175	......	3,899	128									
1897	1,564	165,687	38	1,945	149,038	6,099	718	455	1,496	......	6,992	195									
1898	2,126	151,680	41	2,077	168,795	6,510	874	504	1,485	......	8,121	195									
1899	3,907	156,357	44	2,214	180,699	6,340	1,477	526	2,578	......	4,921	244									
1900	4,463	174,305	33	2,501	207,616	6,430	2,386	981	2,956	......	6.173	751									

1901	4,597	190,108	44	2,074	233,337	8,907	3,060	860	3,921	......	10,997	753	27								
1902	5,644	243,196	52	1,455	220,658	11,348	2,729	970	4,430	......	6,658	786	110								
1903	7,570	275,236	49	1,334	207,099	14,342	3,312	1,222	6,877	......	15,808	762	208								
1904	9,833	319,894	71	1,511	214,582	16,249	3,331	1,740	9,249	......	17,781	792	344								
1905	12,112	369,088	121	1,737	150,575	15,797	3,690	1,537	11,334	......	21,507	1,022	688								
1906	17,474	346,558	148	1,559	161,362	14,981	4,285	1,586	11,003	......	22,414	1,455	1,375								
1907	22,241	455,056	164	2,162	169,455	23,167	4,707	2,074	11,901	......	27,350	2,058	2,753								
1908	22,546	487,778	139	1,443	168,910	34,459	5,112	2,757	13,790	......	28,096	2,582	10,746	33							
1909	25,553	501,839	115	1,153	180,740	40,912	5,170	2,792	18,293	......	30,252	3,866	7,436	49	156						
1910	26,641	574,128	140	866	192,704	34,721	5,011	2,827	16,816	......	30,222	3,447	9,956	55	392						
1911	30,433	603,969	205	797	181,326	28,819	4,759	2,786	17,674	......	33,351	4,014	34,392	36	781	58					
1912	35,453	609,111	148	664	185,844	23,320	4,533	2,817	19,445	......	31,788	4,787	45,241	128	1,194	585					
1913	37,136	680,673	129	625	183,159	21,419	5,315	2,348	21,726	......	31,797	5,674	70,401	359	1,381	269	386	5,088			
1914	35,141	728,117	110	589	178,824	17,633	7,222	2,140	20,301	......	32,459	5,033	71,878	756	1,765	2,063	871	7,973			
1915	32,959	770,148	121	589	189,482	14,663	8,022	1,926	22,471	......	34,004	7,066	90,166	1,406	2,055	581	1,074	9,907			
1916	24,440	821,768	139	541	195,430	17,997	8,096	1,792	23,199	......	35,741	7,085	102,213	2,368	2,538	1,104	1,719	12,232			
1917	10,195	918,674	112	586	172,750	17,063	7,838	1,759	22,134	......	37,343	7,060	151,671	3,337	4,390	2,584	1,485	19,581	618	156	
1918	23,918	975,145	96	836	72,012	16,526	6,688	740	22,433	......	36,360	6,923	175,899	3,706	5,704	5,301	1,381	23,624	1,006	164	995
1919	18,508	1,036,622	96	660	88,233	16,701	6,132	726	23,934	......	43,984	7,200	253,288	3,646	5,044	4,156	1,633	27,778	708	164	915
1920	20,736	1,210,189	96	536	75,842	15,320	6,041	672	22,883	......	47,877	7,697	445,462	4,511	5,961	2,847	2,787	33,415	1,437	164	973
1921	23,391	1,293,652	88	515	79,364	14,156	5,950	751	23,929	......	47,992	10,134	549,544	5,634	6,450	3,438	3,866	45,679	4,104	164	1,066
1922	27,465	1,527,482	85	490	97,786	14,321	5,519	874	23,367	......	48,442	14,559	508,455	7,850	6,700	3,255	7,805	60,951	6,569	164	1,359
1923	30,487	2,005,595	93	466	107,252	14,800	4,796	948	23,030	......	57,387	15,614	415,242	9,137	8,359	2,888	10,795	69,123	13,032	238	1,353
1924	37,127	1,950,656	107	440	123,921	15,456	4,784	1,109	22,995	......	58,904	21,344	384,300	12,729	11,085	3,066	11,374	88,451	25,014	273	1,358
1925	46,585	2,092,447	167	910	143,359	16,329	4,924	1,482	22,668	......	62,012	24,507	317,628	16,406	12,019	3,359	11,663	95,994	55,915	459	1,258
1926	65,181	2,111,984	112	998	174,958	16,011	4,759	1,789	21,948	......	61,432	18,843	247,408	21,506	13,620	3,255	13,540	98,197	101,178	1,042	1,310
1927	73,541	2,468,847	129	1,306	208,943	14,389	4,365	1,816	22,005	......	72,718	27,260	175,739	23,672	14,740	3,471	13,542	108,734	173,087	1,339	1,381
1928	86,180	2,463,044	126	1,715	239,571	14,757	4,844	1,721	23,883	......	84,450	32,283	137,099	24,782	20,994	4,906	14,270	118,746	288,966	2,967	1,399
1929	98,209	2,759,789	135	3,070	282,194	13,383	5,357	2,104	23,965	......	104,228	36,723	122,345	25,730	23,786	5,059	14,917	115,466	376,809	3,701	1,537
1930	119,075	2,460,304	185	4,268	370,782	13,290	5,233	3,520	24,347	......	110,159	34,107	108,231	24,662	24,989	5,229	13,766	125,570	375,308	4,269	1,410
1931	136,900	2,331,729	397	4,338	446,685	12,642	5,165	5,044	23,876	......	93,913	27,641	90,335	32,080	26,635	5,276	10,511	121,578	325,696	4,812	1,419
1932	149,700	2,145,243	663	2,888	421,544	11,132	4,370	4,732	24,091	......	100,698	27,049	89,443	35,883	27,639	4,899	10,369	135,164	322,705	4,358	1,404
1933	151,032	2,481,249	568	2,676	419,408	11,042	3,878	4,715	23,927	......	110,277	36,321	92,822	37,496	26,194	4,301	12,230	148,066	329,978	4,536	1,512
1934	172,353	2,487,849	440	2,767	470,425	10,611	4,173	6,138	25,216	......	120,817	44,600	104,123	38,428	29,847	3,976	13,219	157,271	373,592	4,555	1,535
1935	170,943	2,730,400	343	2,597	497,554	10,322	6,177	8,241	25,280	......	120,856	46,753	109,775	39,167	31,934	3,267	14,304	156,523	407,915	4,806	1,574
1936	177,983	3,004,609	283	2,491	532,607	10,211	6,678	8,504	26,282	......	128,288	48,074	111,527	42,227	36,167	3,283	13,259	170,904	425,992	5,330	1,456
1937	145,625	3,504,548	314	6,368	555 952	10,090	6,835	8,697	5,929	21,433	145,843	47,854	127,919	44,811	42,473	3,081	15,465	212,548	511,934	6,013	1,367
1938	134,050	3,327,000	291	17,521	579,596	10,232	6,806	10,587	6,679	20,663	148,025	43,391	104,875	46,783	47,462	4,550	17,757	213,736	521,842	6,264	1,364
1939‡	127,141	3,465,649	241	20,664	601,734	8,042	6,471	12,823	6,375	21,570	160,554	37,007	117,203	50,999	53,541	12,796	19,383	202,611	562,829	6,461	1,370
1940	116,789	3,697,306	224	23,078	630,000	3,600	5,500	19,754	6,667	21,795	159,821	33,134	119,982	56,314	59,700	17,788	19,619	178,628	508,562	6,532	1,037
1941	109,749	3,841,721	225	26,957	635,000	3,900	4,750	17,214	8,000	20,959	141,918	32,702	117,488	60,315	54,500	23,343	13,731	138,704	625,017	4,385	1,350
1942	116,600	3,799,027	225	27,697	525,000	4,300	4,850	14,523	7,500	3,562	57,879	37,338	95,113	64,942	59,900	22,241	3,700	199,433	405,436	6,418	1,350
1943	109,530	4,124,967	150	26,447	475,000	5,900	4,500	13,973	7,000	2,500	107,884	40,149	95,595	68,063	57,400	24,567	20,000	212,000	491,505	6,518	1,500
1944	71,939	4,584,437	110	26,580	450,000	4,000	4,500	13,607	9,500	2,500	62,968	39,307	103,863	66,205	58,800	25,729	12,500	280,000	702,278	8,107	1,400
1945	94,528	4,694,945	100	22,347	406,000	3,500	4,230	10,402	7,000	1,000	14,200	37,655	118,922	62,769	58,000	25,770	2,800	352,015	885,921	7,298	1,400
1946	86,205	4,750,518	200	19,667	457,060	2,614	3,677	12,382	7,000	1,000	5,753	34,159	134,438	56,926	55,433	24,473	5,754	401,140	1,064,461	6,485	1,071
1947	78,008	5,087,636	236	20,006	543,000	2,600	3,600	11,000	6,137	550	22,000	34,969	153,782	59,855	55,738	25,525	36,084	422,155	1,190,794	6,648	1,041
1948	78,000	5,509,000	200	32,503	600,000	2,700	3,052	12,125	6,300	500	87,800	38,440	160,000	64,835	55,000	35,952	55,200	518,465	1,338,758	7,000	1,071

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* Bureau of Mines and private information.

† Included with India up to 1935.

‡ Commencing in 1939 figures for many countries in the Eastern Hemisphere reflect assumed approximations.

Table 1. World Crude-oil Production, by Countries and Years, 1857 to 1948* (*Continued*)

Year	Czecho-slo-vakia	Great Britain	Co-lombia	Sak-halin	Bo-livia	Iraq	Aus-tria	Bah-rein	Alba-nia	Hun-gary	Saudi Arabia	China	Yugo-slavia	Cuba	Qatar	Brazil	Neth-er-lands	Kuwait	Other coun-tries	Total foreign	Total world
1857–1860	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	13	357
1861	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	47	5,838
1862	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	96	8,471
1863	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	416	7,570
1864	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	514	6,295
1865	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	597	7,441
1866	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	824	10,682
1867	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	993	10,162
1868	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	939	10,902
1869	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	1,318	12,866
1870	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	1,474	15,888
1871	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	1,439	15,699
1872	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	1,596	18,790
1873	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	2,586	29,693
1874	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	2,756	32,693
1875	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	3,259	27,334
1876	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	5,239	30,194
1877	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	6,586	43,162
1878	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	8,274	50,458
1879	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	10,100	64,660
1880	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	10,196	82,016
1881	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	11,868	87,652
1882	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	14,668	97,819
1883	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	18,644	82,890
1884	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	32,108	98,276
1885	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	40,838	100,726
1886	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	52,542	129,433
1887	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	53,490	130,978
1888	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	67,084	142,527
1889	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	72,173	168,512
1890	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	84,406	209,953
1891	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	100,843	249,589
1892	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	104,437	242,456
1893	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	119,471	252,159
1894	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	109,571	244,759
1895	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	139,179	284,088
1896	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	145,462	312,019
1897	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	168,540	334,227
1898	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	190,728	342,408
1899	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	202,950	359,307
1900	...	.....	......	......	.....	.....	.....	.....	....	.....	......	....	.....	...	..	...	....	......	......	234,290	408,595

1901	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	....	268,632	458,740
1902	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	71	254,911	498,107
1903	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	99	258,679	533,915
1904	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	109	275,592	595,496
1905	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	82	220,202	589,290
1906	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	82	237,724	584,282
1907	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	82	268,114	723,17
1908	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	82	291,695	779,473
1909	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	55	316,542	818,381
1910	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	55	323,853	897,981
1911	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	55	339,486	943,455
1912	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	55	356,002	965,113
1913	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	55	387,267	1,067,940
1914	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	58	384,816	1,112,933
1915	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	37	416,529	1,186,677
1916	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	90	436,724	1,258,492
1917	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	104	460,766	379,440
1918	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	87	404,399	1,379,544
1919	132	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	69	503,712	1,540,334
1920	189	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	64	695,248	1,905,437
1921	258	8	182	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	62	826,731	2,120,383
1922	329	3	887	19	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	84	837,338	2,364,820
1923	203	3	1,164	25	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	90	786,525	2,793,120
1924	208	5	1,215	219	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	95	825,579	2,776,235
1925	433	8	2,758	486	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	96	841,425	2,933,872
1926	411	5	17,654	600	60	.....	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	71	895,888	3,007,872
1927	307	5	40,912	1,305	71	920	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	58	985,761	3,454,608
1928	257	3	53,695	2,276	33	1,948	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	62	1,161,933	3,624,977
1929	258	3	54,947	3,288	151	2,186	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	89	1,319,640	4,079,429
1930	426	3	54,670	6,073	152	2,002	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	90	1,431,816	3,892,120
1931	411	3	48,815	6,938	69	2,000	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	90	1,433,269	3,764,998
1932	344	3	43,844	8,230	121	2,000	.....	.....	.....	.....	.....	.....	.....	...	..	...	.....	.....	130	1,433,403	3,578,646
1933	359	.....	35,217	9,341	307	2,501	37	86	.....	.....	.....	.....	.....	...	..	...	.....	.....	163	1,468,990	3,950,239
1934	527	.....	46,410	8,976	435	21,896	67	784	.....	.....	.....	.....	.....	...	..	...	.....	.....	....	1,663,181	4,151,030
1935	404	.....	47,218	7,672	449	76,359	110	3,465	.....	.....	.....	.....	.....	...	..	...	.....	.....	....	1,794,008	4,524,408
1936	397	.....	50,502	8,832	286	83,089	110	12,691	1,000	.....	.....	.....	.....	...	..	...	.....	.....	....	1,908,453	4,913,062
1937	337	.....	54,944	9,300	334	88,000	572	21,267	1,603	55	.....	.....	.....	...	..	...	.....	.....	....	2,096,963	5,601,511
1938	397	.....	58,925	9,315	373	88,877	1,089	22,734	2,315	908	1,370	.....	.....	...	..	...	.....	.....	....	2,128,777	5,455,777
1939‡	325	88	64,835	10,601	589	82,079	2,839	20,791	3,027	3,069	10,778	.....	.....	...	..	...	.....	.....	....	2,228,836	5,694,485
1940	500	358	69,136	11,270	787	51,498	8,057	19,388	4,000	5,339	13,866	.....	.....	...	..	...	.....	.....	....	2,172,723	5,870,029
1941	525	632	66,816	12,000	644	31,632	12,222	18,600	3,507	8,944	11,809	.....	.....	18	57	...	.....	.....	75	2,207,613	6,049,334
1942	575	1,656	28,732	11,000	843	51,570	17,000	17,100	4,775	14,020	12,412	1,000	1,000	13	15	...	.....	.....	28	1,819,718	5,618,745
1943	600	2,298	36,316	10,000	915	74,658	21,610	18,000	3,000	17,605	13,337	1,500	1,500	5	..	132	4	.....	141	1,971,661	6,096,628
1944	550	1,912	60,904	.....	858	86,899	23,707	18,344	.....	16,951	21,296	1,500	2,000	73	..	157	33	.....	263	2,179,077	6,763,514
1945	500	1,452	61,530	.....	1,046	95,797	8,886	20,024	1,000	13,751	58,386	2,000	1,000	292	..	217	112	.....	621	2,381,850	7,076,795
1946	525	1,129	60,596	.....	1,100	96,712	16,566	21,945	1,000	14,097	164,229	2,000	1,000	564	..	185	1,195	16,249	18,193	2,778,990	7,529,508
1947	658	959	68,063	.....	1,340	99,191	15,963	25,783	1,000	11,868	246,169	1,084	1,000	685	..	265	4,050	44,460	49,460	3,196,266	8,283,902
1948	400	881	64,905	.....	1,124	70,570	15,000	29,822	1,000	10,000	390,309	1,800	1,100	309	..	384	9,410	127,207	137,310	3,822,122	9,332,526

* Bureau of Mines and private information.

‡ Commencing in 1939 figures for many countries in the Eastern Hemisphere reflect assumed approximations.

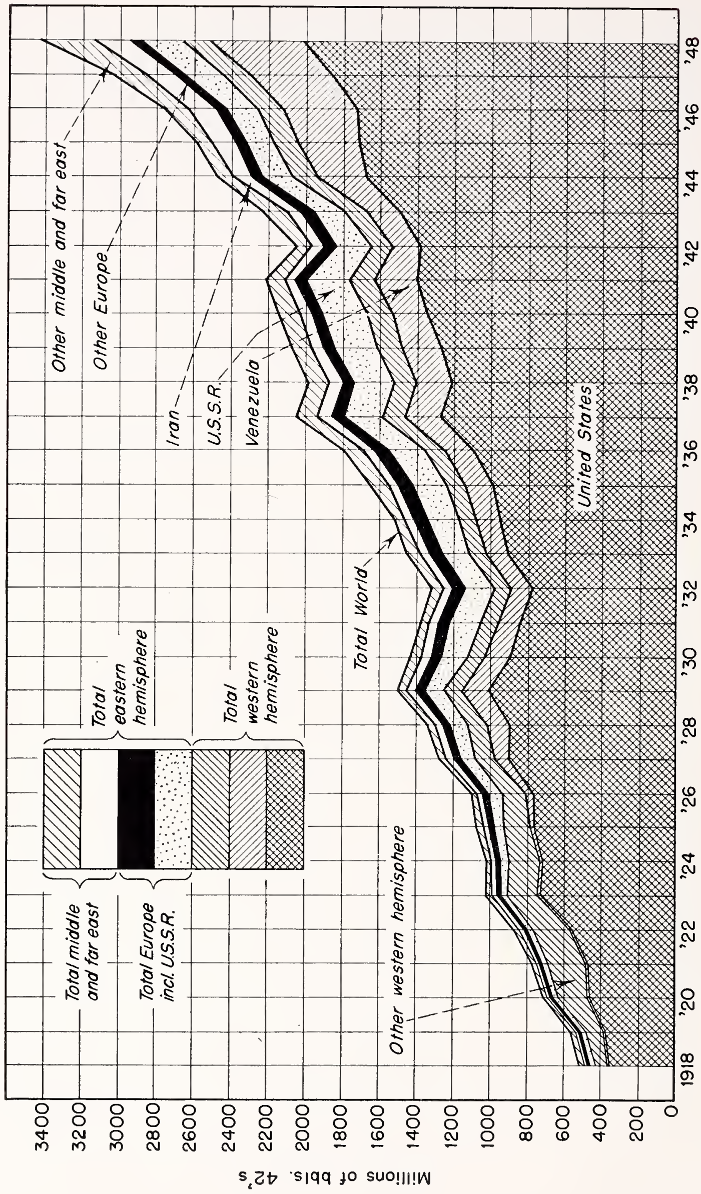

FIG. 1. World crude-oil production.

its division between United States and foreign areas, and the volume of the American share therein between 1900 and 1922:

Comparative Oil Production, 1900 to 1922
(Millions of barrels daily)

Year	Total world	Total United States	Per cent of world	Foreign					
				Total foreign	Russia	Total foreign except Russia	American owned foreign	Per cent of total foreign	Per cent of total foreign except Russia
1900	0.41	0.17	43	0.24	0.21	0.03			
1910	0.90	0.57	64	0.33	0.19	0.14	0.01	2	6
1912	0.97	0.61	63	0.36	0.19	0.17	0.03	8	18
1914	1.11	0.73	65	0.38	0.18	0.20	0.05	13	24
1918	1.38	0.98	71	0.40	0.07	0.33	0.13	32	39
1920	1.91	1.21	64	0.70	0.08	0.62	0.33	48	53
1922	2.36	1.53	65	0.83	0.10	0.73	0.42	50	57

American participation in foreign production thus rose rapidly during those years, reaching an all-time peak in 1922 of about 50 per cent of total foreign production.

Developments during the First World War set the stage for the second phase of American interest in foreign oil—from about 1922 to the present time. During this period American oilmen have established themselves strongly in most of the important areas with the exception of Russia. The First World War had made great demands on the petroleum resources of the United States, which resulted in a 60 per cent increase in domestic production between 1912 and 1918. The demand for petroleum products reached new high levels in the immediate postwar period, and fears of an oil shortage were voiced in the United States.

In the early twenties the United States government strongly urged that American oil interests expand abroad and develop adequate reserves to supplement what appeared at that time to be the dwindling supply at home. A sign of the times may perhaps be seen in the fact that in 1926 the Federal Oil Conservation Board, appointed by President Coolidge to study the petroleum picture, estimated officially that proved reserves in the United States were only 4½ billion barrels—equivalent to only 6 years supply.

With the strong diplomatic backing of their government, American operators embarked on exploratory efforts in many parts of the world. American geologists during the early and middle twenties were active on every continent of the globe. Even today much of the available knowledge of oil prospects in many inaccessible and undeveloped regions stems from these far-flung ventures. American drilling equipment was soon being dispatched to most of these outposts, and many new producing areas in which American capital participated were discovered during the first postwar decade. At least 40 American concerns are known to have been active in foreign production and exploration during this period.

Large oil reserves were developed abroad by Americans in the course of this intensive search. But along with success overseas came the discovery of many large fields in the United States. The downward trend in the ratio between production and proved reserves was halted. Public interest in the activity abroad and also the strength of government support declined. Many operators, particularly the smaller ones, were lured back from the foreign field to the United States by the changed picture at home and the realization that most foreign operations require extended, difficult negotiations and large, long-range expenditures before commercial production can be established.

The advent of the Second World War changed the picture again. The greatest American-owned foreign interests were in the Caribbean and Middle East areas. These, fortunately, were beyond the reach of the Axis powers, and on them fell a great part of America's responsibility for fueling the Allied war machine.

Then, after the Second World War, the world demand for oil continued to increase. In America factories began turning out more equipment than ever before, to meet long pent-up civilian desires. Abroad, in the war-damaged countries of the Allies, there was great need for oil to rebuild and refuel shattered industries, agricultural tools, and transportation facilities. Some of the oil used abroad came from American wells, but domestic production could not meet the entire increase. Oil fields in Venezuela, Kuwait, Saudi Arabia, and Bahrein—mostly American-owned—were developed to produce more and more oil.

The trend of American-owned oil production abroad since the

First World War is reflected by the following table of comparative production for selected years between 1923 and 1949:

Comparative Oil Production, 1923 to 1949
(Millions of barrels daily)

Year	Total world	Total United States	Per cent of world	Foreign					
				Total foreign	Russia	Total foreign except Russia	American owned foreign	Per cent of total foreign	Per cent of total foreign except Russia
1923	2.79	2.01	72	0.78	0.11	0.67	0.31	40	46
1926	3.01	2.11	70	0.90	0.17	0.73	0.28	31	38
1929	4.08	2.76	68	1.32	0.28	1.04	0.39	30	38
1932	3.58	2.15	60	1.43	0.42	1.01	0.33	23	33
1935	4.52	2.73	60	1.79	0.50	1.29	0.46	26	36
1938	5.46	3.33	61	2.13	0.58	1.55	0.51	24	33
1941	6.05	3.84	63	2.21	0.64	1.57	0.61	28	39
1942	5.62	3.80	68	1.82	0.53	1.29	0.36	20	28
1943	6.10	4.12	68	1.97	0.48	1.49	0.44	22	30
1944	6.76	4.58	68	2.18	0.45	1.73	0.66	30	38
1945	7.08	4.69	66	2.38	0.41	1.97	0.82	34	42
1946	7.53	4.75	63	2.78	0.46	2.32	1.05	38	45
1947	8.28	5.08	61	3.20	0.54	2.66	1.22	38	46
1948	9.33	5.51	59	3.82	0.60	3.22	1.53	40	48

Although the volume of American-owned foreign production increased steadily over the *interwar* period, reflecting the results of previous exploratory efforts, the percentage participation declined from the levels of the middle twenties. One reason for this decline lay in the revival of Russian production. Another reason is that companies of other countries, especially the British and Dutch, with ability and initiative equal to American efforts, secured concessions in areas such as Iran, Iraq, Trinidad, and the Far East, all of which underwent great expansion in oil production following the First World War.

However, when the great demands for oil during the Second World War and thereafter arose, the American concessions that had been secured abroad in the thirties were ready for expansion.

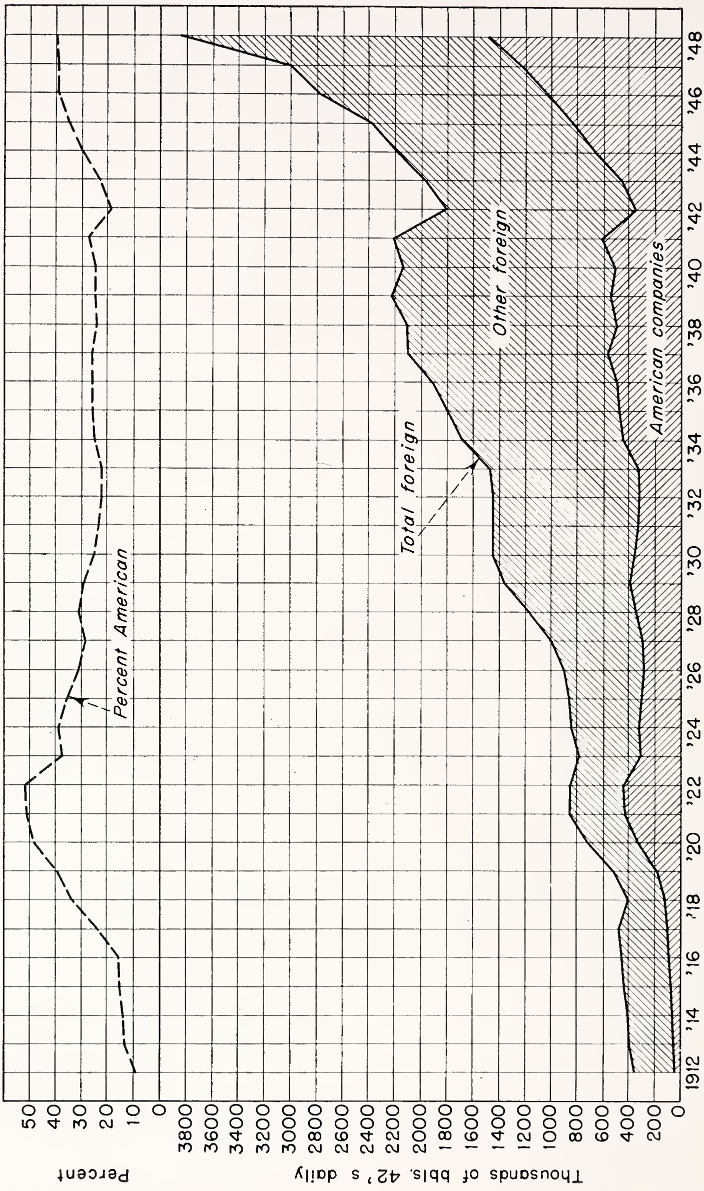

FIG. 2. American participation in estimated foreign crude-oil production.

TABLE 2. FOREIGN CRUDE-OIL PRODUCTION—MAJOR NATIONALITIES*
(Barrels of 42 U.S. gal daily)

Year	American companies	British and Dutch companies	Russian government	All others	Subtotal	Total foreign companies
1912	29,908	103,825	....	222,268	....	356,001
1913	46,772	126,635	....	213,859	....	387,266
1914	49,480	148,020	....	187,315	....	384,815
1915	63,068	151,829	....	201,632	....	416,529
1916	69,551	162,966	....	204,207	....	436,724
1917	104,464	173,522	....	182,780	....	460,766
1918	129,944	163,178	....	111,277	....	404,399
1919	195,596	179,994	88,233	39,889	....	503,712
1920	330,347	246,497	75,842	42,562	....	695,248
1921	415,214	278,181	79,364	53,972	....	826,731
1922	421,858	263,285	97,786	54,409	....	837,338
1923	311,415	312,902	107,252	54,956	....	786,525
1924	328,657	306,649	123,921	66,352	....	825,579
1925	304,936	316,662	143,359	76,468	....	841,425
1926	276,446	352,939	174,958	91,545	....	895,888
1927	293,033	391,645	208,943	92,140	....	985,761
1928	354,119	470,582	239,571	97,661	....	1,161,933
1929	392,103	541,211	282,194	104,132	....	1,319,640
1930	368,285	573,625	372,587	117,319	....	1,431,816
1931	332,550	522,542	449,147	129,030	....	1,433,269
1932	328,326	550,177	425,290	129,610	....	1,433,403
1933	340,127	567,448	424,216	137,199	....	1,468,990
1934	417,079	632,914	475,494	137,694	....	1,663,181
1935	461,977	665,512	502,732	163,787	....	1,794,008
1936	484,273	707,553	538,189	178,438	....	1,908,453
1937	562,869	810,807	562,022	161,267	1,534,943	2,096,965
1938	506,978	810,051	585,969	225,779	1,542,808	2,128,777
1939	554,899	795,393	609,656	268,888	1,619,180	2,228,836
1940	528,406	708,742	638,675	296,900	1,534,048	2,172,723
1941	610,640	656,071	644,465	296,437	1,563,148	2,207,613
1942	358,750	554,452	533,600	372,916	1,286,118	1,819,718
1943	438,424	596,032	483,500	453,705	1,488,161	1,971,661
1944	655,335	707,783	450,000	365,886	1,729,004	2,179,004
1945	818,243	812,956	406,000	344,651	1,975,850	2,381,850
1946	1,047,014	934,098	457,060	340,827	2,321,939	2,778,999
1947	1,219,500	1,082,700	543,000	351,100	2,653,300	3,196,300
1948	1,484,900	1,327,800	600,000	409,500	3,222,200	3,822,200

* Partly estimated.

American ingenuity and equipment were poured into those concessions, and the result was the greatest output of oil that the world has ever seen.

Activities in Principal Producing Areas

Principal developments connected with American participation in the more important foreign producing areas (Fig. 2 and Table 2) are reviewed in more detail on pages 36 and 37.

Mexico. An independent American operator entered Mexico in 1883, but oil was not actually introduced until 1900, when another American operator purchased a hacienda in northern Mexico and in the following year found oil at a shallow depth in the Ebano field. Between 1901 and 1908 several successful wells were completed in various areas and production reached 10,000 bbl daily in 1908. But not until 1908, when the famous Dos Bocas well came in, caught fire, and burned for almost two months, was attention from the outside world focused on Mexico. The year 1910 was also eventful because of the completion of another famous well, Potrero del Llano No. 4, which flowed wild for 60 days at an estimated rate of over 100,000 bbl daily and opened what proved to be the Golden Lane between the Panuco and Túxpam Rivers. By 1911 Mexican production had reached 34,000 bbl daily, of which more than half was American-owned, and proved reserves were estimated between 600 and 700 million barrels.

The collapse of the Russian oil industry in the First World War, together with the increased use of oil-burning ships for commercial and military purposes, created a tremendous demand during the war for heavier grades of crude oil, such as those produced in Mexico. The country therefore underwent its greatest expansion during and immediately following the First World War.

The development of Mexican production, between the period 1912 to 1922, is shown in the table on the opposite page.

During the period of greatest development more than 25 American concerns were active in producing Mexican oil. At the height of this activity the country became the world's greatest petroleum exporter.

The producing fields in the Golden Lane started showing water in 1920, but new areas were discovered which not only helped retard the decline but even expanded output to an all-time peak of 550,000 bbl daily in 1921. The discovery of new areas did not continue at a rate sufficient to offset the decline of the older fields, and during the next five years Mexico's output was reduced by over 50 per cent. In the ensuing years output declined still further, never again attaining the early levels.

This decline in new discoveries and total output began coincidentally with the beginning of many long-continuing difficulties between Mexican labor and politics on the one hand and the oil operators on the other. Despite the fact that many efforts were made to settle disputed questions, conditions became steadily worse, culminating in the Expropriation Decree of Mar. 18, 1939.

Development of Mexican Production, 1912 to 1922
(Barrels daily)

Year	Production	American-owned production	Per cent American-owned
1912	45,200	25,900	57.3
1913	70,400	40,300	57.2
1914	71,900	41,200	57.3
1915	90,200	51,600	57.2
1916	102,300	58,600	57.3
1917	151,700	99,500	65.6
1918	175,900	124,800	70.9
1919	253,300	187,900	74.2
1920	445,500	320,800	72.0
1921	549,500	401,900	73.1
1922	508,500	404,200	79.5

The government, after expropriation, developed no new resources, and Mexico's position as a world source of oil deteriorated steadily.

Until the end of 1948, Mexican fields had produced 2,370 million barrels, with a remaining proved reserve of over 950 million barrels, all of which were located in fields discovered by the expelled private owners.

Since the end of the Second World War, however, the Mexican government has made overtures to private interests in the United States, inviting participation in oil developments. Early in 1949 a newly formed company of American oilmen announced an agreement with the Mexican government to resume active exploration and development work on a contract basis.

Venezuela. Prior to 1912, petroleum developments in Venezuela were confined to the exploitation of seepage oil in southwestern Venezuela by a local company, which also carried on small refining operations, the products of which were sold for local consumption. In 1907, several large blanket concessions for asphalt were granted to Venezuelans. In 1910, an American company, which also owned a concession on a large asphalt lake in eastern Venezuela, obtained concessions for oil rights in the vicinity of Lake Maracaibo and in eastern Venezuela. In 1913, this operator completed the country's first oil well, located in eastern Venezuela, and although the discovery was not developed, it ushered in the intensive exploration of Venezuela's oil resources, which for many years made it second only to the United States in the world oil picture. Today, Venezuela is firmly in first place among foreign producers.

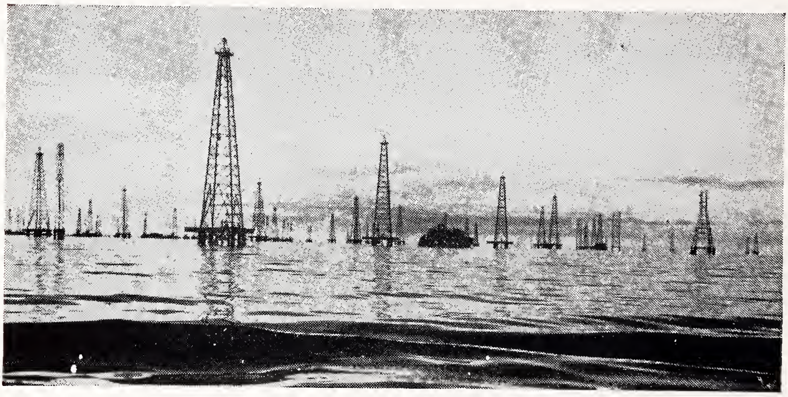

Fig. 3. Tia Juana field on Lake Maracaibo, Western Venezuela.

British-Netherlands interests became very active in the country between 1913 and 1920 and for a time held more extensive concessions than Americans, whose interest did not take the form of active search until the early twenties. By 1920, 29 wells had been drilled in Venezuela, resulting in four discoveries with an estimated reserve of around 400 million barrels. Production amounted to about 1,000 bbl daily. In 1920, the Venezuelan government passed a petroleum law which was widely regarded as providing a mutually equitable base for oil development. By this time it was evident that Venezuela's oil resources were vast, and the government's encouragement of foreign capital gave a great stimulus to exploration. Some 35 American companies started to acquire petroleum exploratory concessions and carried out exploratory work to such good effect that by 1925 the estimated proved reserves of the country had increased to around 900 million barrels.

After 1925, American-owned production in Venezuela rose rapidly in both amount and percentage of the total to over 50 per cent in 1928. It has increased still further since then, and at the height of the Second World War it accounted for more than 70 per cent of the total.

The following table shows the course of production in Venezuela and the American-owned share, from 1921 to the present:

VENEZUELA—INDUSTRY AND AMERICAN-OWNED CRUDE-OIL PRODUCTION
(Barrels daily)

Year	Industry production	American-owned production	Per cent American-owned
1921	4,100		
1922	6,600	36	0.5
1923	13,000	200	1.5
1924	25,000	1,200	4.8
1925	55,900	17,500	31.5
1926	101,200	37,400	37.0
1927	175,100	83,400	47.6
1929	376,800	206,300	54.8
1932	322,700	171,600	53.2
1936	426,000	256,300	60.2
1939	562,800	335,100	59.5
1940	508,600	312,200	61.4
1941	625,000	403,500	64.6
1942	405,500	247,000	60.9
1943	491,500	317,500	64.6
1944	702,300	496,400	70.7
1945	885,900	622,300	70.2
1946	1,064,500	744,100	69.9
1947	1,190,800	805,700	67.7
1948	1,458,700	936,300	64.2

Up to the end of 1948, Venezuela had produced 4,537 million barrels of oil, and proved crude-oil reserves at the end of 1948 have been estimated at close to 8,000 million barrels, of which Americans have rights to nearly 71 per cent.

Of particular interest in the Venezuelan petroleum picture are the unique overwater oil operations in Lake Maracaibo, where an American company developed means of drilling and producing in water over 100 ft in depth, an exceptional engineering feat and one that opened vast oil reserves that would otherwise have remained untapped.

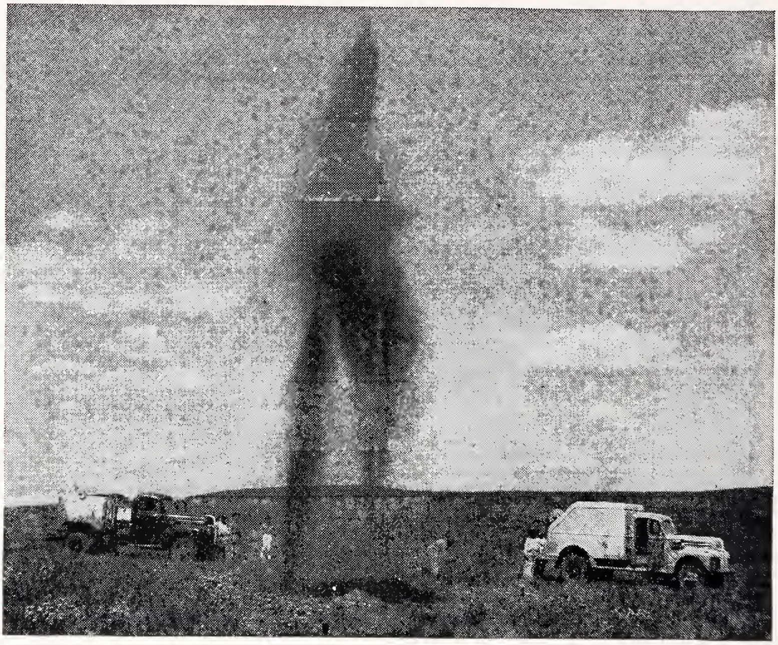

Fig. 4. Colombia. Seismograph operations on the llanos.

Colombia. Exploration for petroleum began along the northern coastal plain of Colombia in 1908. Records mention that a Colombian company financed by American and Colombian capital found a small amount of oil, but no commercial production was obtained. In 1909 this company opened a refinery at Cartagena with a capacity of 400 bbl daily and operated it on crude oil imported from the United States.

The first commercial discovery of oil was made by a small American operator in 1918 in the jungles of the Upper Magdalena River

Valley, some 300 miles from the coast. In 1920 the rights were sold to one of the major American companies, which, through an affiliate, undertook development. A refinery was erected in 1922 adjacent to the fields to supply local markets, and in 1926 a 335-mile pipe line to the seacoast (a tremendous engineering achievement at the time) was completed and Colombian crude oil began to reach the world market.

In 1917 another American company had become interested in a large concession in eastern Colombia bordering on Venezuela. Because of legal entanglements exploration did not start until early in 1930, and the first producing well was completed only in 1933. Development proceeded slowly until a pipe line was completed in 1938 over a nearby mile-high branch of the Andes to the coast.

Since completion of the first pipe line in 1926, Colombia's production has ranged between 40,000 and 69,000 bbl daily, fluctuating with export market and shipping conditions. All production prior to 1945 was under American control, but in 1945 a British-Netherlands company brought in its own commercial production. At the end of 1948, 437 million barrels of oil had been produced in Colombia, and reserves were estimated at over 335 million barrels, of which about 37 per cent were American-owned.

Colombia's oil laws have long contained various restrictive provisions which have hindered intensive exploratory work, but during the past quarter of a century many American companies, both large and small, have held acreage in Colombia and drilled exploratory wells, while several companies of other nationalities have also been interested at one time or another. The country has not, however, had the same intensive development apparent in Venezuela, probably because of the less favorable terms of the law.

Peru. In Peru, small oil production under British control dated from 1896, but American interests acquired the properties in 1915 and materially increased production, maintaining it at a level of 20,000 to 48,000 bbl daily. There has been some other small production by British and local interests, but American control has risen to some 80 per cent of the total for the last 20 years; at the end of 1948, American-owned reserves represented 72 per cent of the country's total. Practically all Peruvian crude is refined in Peru, at an American-owned refinery.

Most commercial production to date has been located in the extreme northern part of the country along the seacoast, but an American operator made the first discovery of oil in the relatively inaccessible trans-Andean section of Peru. The oil output of this area, although small, is refined locally, and the products are marketed in the interior areas. As in Colombia, Peru's oil laws have been regarded by operators as containing hindrances and restrictions which have served to retard intensive exploratory efforts.

Other Areas of the Western Hemisphere. An American-owned company in Ecuador had, by the end of 1947, spent more than 12 million dollars in oil exploration, without success. That company has since entered a joint effort with a foreign company to continue development work.

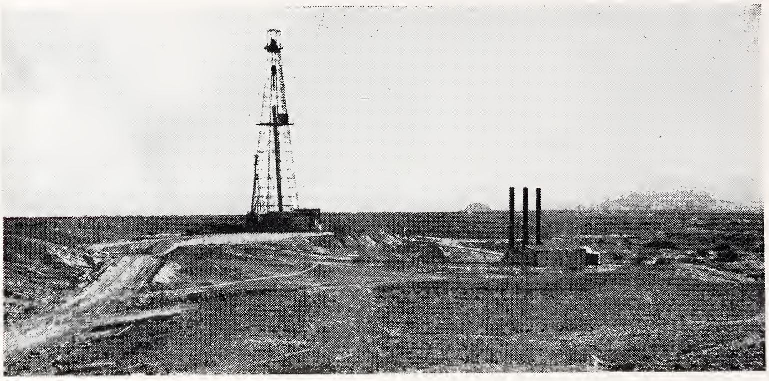

Fig. 5. Peru. Wildcat well on the southern border of the field. Only by drilling can the exact producing limits be determined, for the structure is made up of a myriad of stratigraphic traps which make geology almost useless.

It had long been known that oil existed in Chile, but it was not until 1945 that American geologists and American drillers, working for the Chilean government, brought in that country's first producing wells in the Tierra del Fuego area.

Intensive exploratory efforts by American companies in Cuba and the Bahama Islands have so far failed to find worth-while amounts of oil, but work is continuing, and there is every reason to believe that present efforts will meet with ultimate success.

Probably the most exciting new development in the Western Hemisphere since the Second World War, however, has taken place in Canada. Oil was first discovered by Americans, in small amounts, near Calgary in 1914 and at Norman Wells, near the Arctic Circle, in 1920. Other fields were brought in at Turner Valley in 1924 and at Lloydminster in 1939. All four of these fields lie widely scattered in the central part of Canada, which is known as the Prairie Provinces.

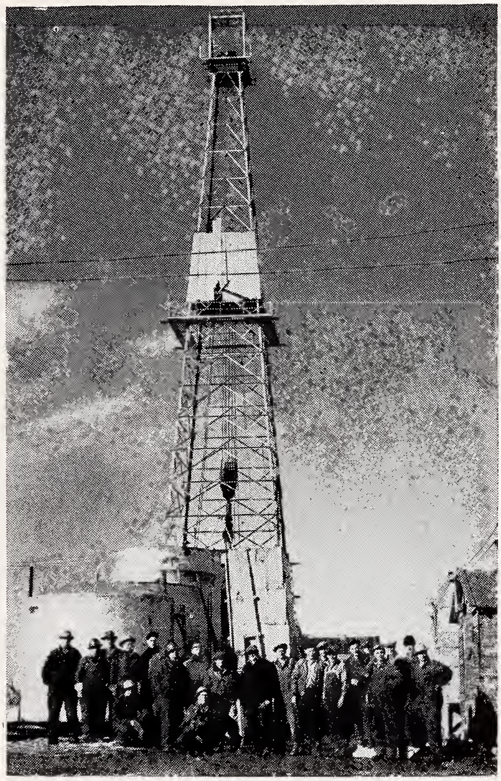

FIG. 6. Canada (near Leduc, Alberta). Part of the drilling crew that successfully completed the Imperial Oil Company's well Leduc No. 1.

Then, in 1947, a Canadian affiliate of an American company discovered the Leduc field, near Edmonton, in Alberta. Other operators quickly entered the area; by the end of 1948, American and Canadian companies had found several more oil fields. The Prairie Provinces give every indication of becoming one of the hemisphere's most important sources of oil.

Europe. Many European countries have small oil fields within their borders, but very few produce appreciable amounts. Of the European oil-producing countries, Rumania was the most important. Rumania began producing oil long before the turn of the present century (see Table 1) and in fact had a very small oil industry based on shallow, hand-dug wells two years before the drilling of the Drake well in the United States. Production developed slowly, however, until after 1900. It was mentioned earlier that an American company first entered Rumania in 1903. By 1914 the American share was 8,300 bbl daily, or 24 per cent of the total for the country. This share declined after the First World War, however, and by the beginning of the Second World War, during which all the oil fields were taken over by the Axis powers, the American share had dropped to 11.4 per cent. After the war the American company which held the principal interest returned and tried to salvage what was left of its property, but Communist-inspired government interference prevented any real rehabilitation. American interests were taken over by the Communists in 1948.

Hungary, where oil was discovered by an American company in 1937 (after Hungarian government geologists had flatly stated that no oil existed) rapidly became an important European producer. After the beginning of the Second World War, however, its story parallels that of Rumania. All American oil-company representatives were expelled from Hungary by the Communists in 1948, and control of the oil properties taken over by the government.

Since the Second World War a joint local and American company has developed oil production in the Netherlands to approximately 11,500 bbl daily by the end of 1948.

East Indies. The first oil production in the East Indies was developed by Netherlands interests in 1893, and for many years thereafter all operations were confined to nationals, who had exclusive preference on state land Americans discovered a small amount of oil in 1914 on land secured from private owners, but such output did not exceed 3,500 bbl daily, or 5 per cent of the Dutch East Indies total up to 1927. In 1928, however, after a number of years of strenuous intervention by the U.S. State Department for recognition of the open-door policy, rights to explore government lands were granted to Americans on an equal basis with Netherlands companies. Discoveries were made shortly thereafter by Americans on the new concessions, and active development followed, with the result that by 1939 the American share in the industry amounted to 27 per cent of production and 35 per cent of reserves.

The East Indian fields were deliberately sabotaged by the American operators under government order just before Japanese forces moved into the islands in 1942. After the war, when the Americans were able to return, production was soon restored to the prewar level.

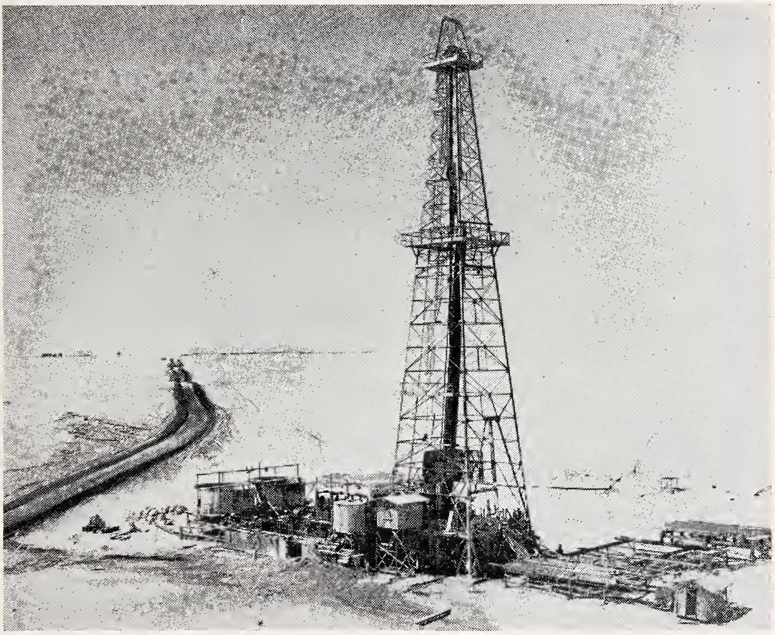

FIG. 7. Drilling rig on the desert near Abqaiq. The road to the left connects Abqaiq, which can be seen on the horizon, with Dhahran, Aramco's headquarters in Saudi Arabia.

Late in 1948 an oil company in which Americans have a part began commercial production from a new field in western New Guinea. This development represents an important addition to the Far East's crude-oil supplies.

Middle East. The story of petroleum in the Near East stretches back to the dawn of history, when seepage oils and tar were utilized for a multitude of purposes, but little or no modern drilling had been done up to the First World War. With the breakup of the

Turkish Empire, British, Dutch, and French interests took up rights to explore in various of the newly set-up mandates and protectorates.

During 1919, American companies became interested in the possibilities of Mesopotamia, formerly part of the Turkish Empire and now known as the kingdom of Iraq, but had no success in relaxing the British-French hold on the area. Two years later the U.S. State Department started negotiations with the British and other governments for the adoption of an open-door policy in respect to the Mesopotamian oil properties. The State Department, however, required assurance that, if an opportunity were presented, American companies would be prepared to dispatch an adequate geologic investigating party to make preliminary examinations of this supposed oil territory. Seven American companies indicated a desire to participate and in November, 1921, addressed a joint letter to the Secretary of State stating that they were prepared to send the necessary experts for a reconnaissance survey of Iraq. About one year later, on 1922, representatives of the American group sailed for Europe to represent the seven companies in negotiations with the Turkish Petroleum Company.

Because the small participation offered to the American group appeared entirely unacceptable, the American representatives terminated the discussions and returned to the United States. Only after six years of protracted negotiations was an agreement formulated in the middle of 1928 which satisfactorily conformed to the State Department's open-door policy, and the American companies became partners with British, Netherlands, and French interests to develop the resources of Iraq. American participation was fixed at 23¾ per cent and was divided among the five remaining American companies. Subsequently three of the original American partners withdrew, selling their interests to two of the original American participants in the Turkish Petroleum Company agreement.

Drilling operations began in April, 1927, and the first well was completed on the Kirkuk structure in October. The well came in out of control and flowed at an estimated rate of over 100,000 bbl daily. Subsequent drilling proved the existence of a field of great proportions, and a pipe line was constructed by American engineers to the Mediterranean, 620 miles distant, with exports commencing in the fall of 1934.

Just before the beginning of the Second World War, Iraq's production had been averaging about 88,000 bbl daily. Since the war, production there has averaged about 90,000 bbl a day and reached a peak of 99,000 bbl a day in 1947.

In the middle thirties other American companies secured concessions in the Persian Gulf area through the active diplomatic support of the U.S. State Department. By 1939, very large discoveries had been made in Bahrein Island, Saudi Arabia, and Kuwait. Refineries were built on Bahrein and at Ras Tanura in Saudi Arabia, and both of these refineries contributed huge volumes of oil products to the Allied forces in the Pacific.

Americans hold concessions on 100 per cent of the Saudi Arabian and Bahrein reserves so far developed, which are rated at several billion barrels, and on 50 per cent of those of Kuwait, where reserves are also great. In 1948, other American companies obtained concessions in the two Neutral Zones which border on western Saudi Arabia.

The oil fields of Saudi Arabia are potentially the greatest known to exist today. Production there increased from 1,400 bbl a day in 1938 to 466,000 bbl a day by the end of 1948. The estimated proved reserves of Saudi Arabia are 6,732 billion barrels. A large part of Saudi Arabian oil, as well as that from other Middle East fields, is consumed in Europe. Since the Second World War the output of these fields has been vitally important in the rehabilitation of the war-torn countries west of the Iron Curtain.

American companies have never owned production in Iran (Persia), the other great oil source of the Middle East, where oil operations to date have remained exclusively in the hands of a British concern, which began production there in 1911.

A new oil field was discovered in Egypt in 1947 by an American oil company. Full development of Egyptian oil resources by Americans, however, has been hampered by the restrictive policies of that government. In Ethiopia another American company has development concessions, but no oil had been discovered there prior to the end of 1948.

Other Areas. Aside from the major oil areas discussed above, American companies have also produced oil in many other countries. In fact the only foreign producing areas of any present importance in which American companies have not been represented are India, Burma, Japan, Sakhalin, Iran, British Borneo,

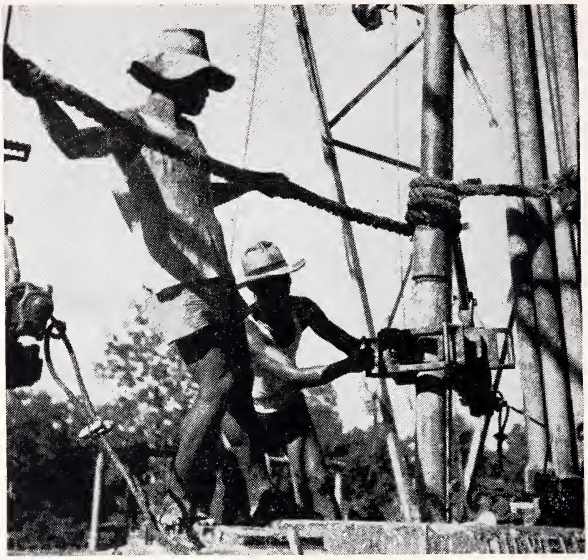

Fig. 8. Sumatra. Drill floor crew screwing drill pipe together.

and Russia, and their absence from these is largely due to restrictions by the local governments.

The table below gives pertinent statistical data on producing countries not reviewed above but in which American oil companies

Minor Countries—American-owned Crude-oil Production

Country	First oil discovered	First American production	Latest Reported American production, bbl daily	Per cent of total
Bolivia*..........	1926†	1926	0	0
Poland...........	1874	1920	0	0
Italy.............	1865	1927	100	50
Netherlands......	1943	1947‡	5,850	50
Germany.........	1880	1933	0	0
Austria..........	1933	1938	0	0
Hungary.........	1937†	1937	0	0
England..........	1918	1939	3	0.3
Argentina........	1907	1926	1,800	2.8
Trinidad.........	1908	1928	100	0.2

* Property expropriated.
† Americans made the first oil discoveries in these countries.
‡ 50 per cent interest purchased in 1947 retroactive to 1943.

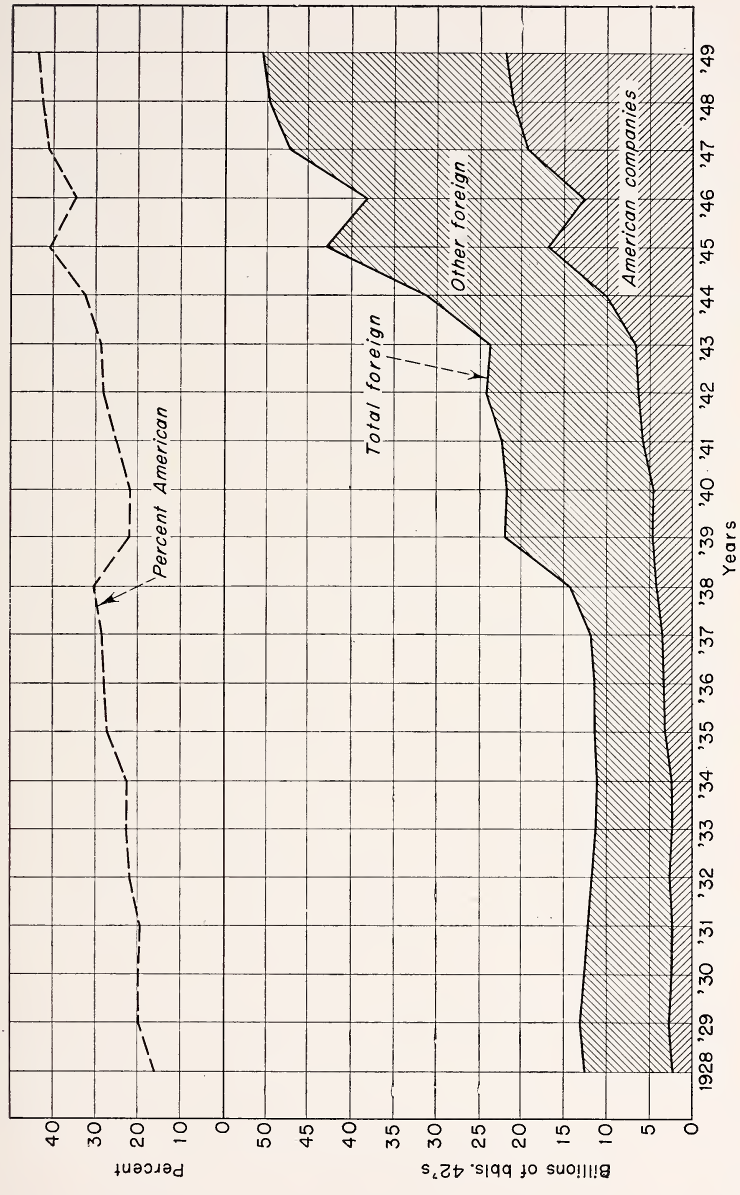

FIG. 9. Estimated proved crude-oil reserves in foreign countries, showing quantity and percentage American-owned.

have participated. With the exception of Trinidad all are of minor importance, although the activities are, of course, significant in the local economies of most of the areas.

PROVED CRUDE-OIL RESERVES

The development of foreign oil reserves by Americans parallels the developments of production reviewed above. The estimated proved oil reserves abroad at the end of each year since 1927 are shown in Table 3 and Fig. 9. Data for previous years are not available. These figures are summarized below. (Reserves owned by Americans, but controlled by the enemy during the Second World War, are credited to American ownership.)

ESTIMATED PROVED CRUDE-OIL RESERVES, JAN. 1, 1949*
(Thousands of barrels)

Area	Industry	American	Per cent American
North America except United States	1,353,000	370,000	27.3
Caribbean area	9,550,000	7,232,000	75.7
Other South America	480,000	190,000	39.6
Total Western Hemisphere Except United States	11,383,000	7,792,000	68.5
Europe except Russia	604,000	48,040	8.0
Near and Middle East	32,621,000	13,732,320	42.1
Other Eastern Hemisphere	1,439,000	488,320	33.9
Total Eastern Hemisphere except Russia and Sakhalin	34,664,000	14,268,680	41.2
Total foreign except Russia	46,047,000	22,060,680	47.9
Russia and Sakhalin	4,275,000	0	0
Total foreign	50,322,000	22,060,680	43.8

* DEGOLYER AND MACNAUGHTON, "*20th Century Petroleum Statistics.*"

REFINING

The data available on American-owned refining operations abroad are very scanty for the years prior to 1927, only general trends being ascertainable.

TABLE 3. ESTIMATED PROVED CRUDE-OIL RESERVES IN FOREIGN COUNTRIES*
(Thousands of barrels)

Year	Total foreign	American companies	Per cent American of total foreign	Total foreign except Russia	Per cent American of total foreign except Russia
Jan. 1, 1928	12,597,189	2,080,216	16.51	9,175,179	22.7
1929	13,036,445	2,592,961	19.89	9,702,118	26.7
1930	12,664,932	2,519,227	19.89	9,433,606	26.7
1931	12,190,353	2,423,225	19.88	9,094,362	26.6
1932	11,709,744	2,505,456	21.40	8,776,793	28.5
1933	11,284,668	2,497,868	22.14	8,506,002	29.4
1934	11,003,560	2,447,836	22.52	8,177,978	30.3
1935	11,203,574	3,054,363	27.26	8,796,160	34.7
1936	11,428,860	3,180,649	27.83	9,692,972	32.8
1937	11,727,218	3,290,692	28.06	9,968,757	33.0
1938	14,278,582	4,329,367	30.32	12,375,308	35.0
1939	21,822,424	4,820,785	22.09	19,698,999	24.5
1940	21,801,986	4,727,819	21.69	19,684,160	24.0
1941	22,440,983	5,637,909	25.12	20,299,757	27.8
1942	24,058,823	6,572,646	27.32	21,553,752	30.5
1943	23,920,743	6,690,608	27.97	21,528,797	31.1
1944	31,431,522	10,233,468	32.56	25,769,924	39.7
1945	43,419,800	17,371,700	40.1	37,554,800†	46.3‡
1946	38,085,000	13,465,900	35.4	30,023,000†	44.9‡
1947	47,636,000	19,099,300	40.1	38,074,300†	50.2‡
1948	49,695,350	21,086,400	42.4	42,105,350†	50.1‡
1949	50,322,000	22,060,680	43.8	46,047,000†	47.9‡

* Source: Jan. 1, 1928 to Jan. 1, 1943—private sources. Jan. 1, 1944, Russia—PAW, January, 1944. Jan. 1, 1944, Iran, Iraq, Kuwait, Bahrein, Arabia, and Qatar—DeGolyer, March, 1944, 1945—presented to Special Senate Committee Investigating Petroleum Resources, 1945-1946, 1946 to 1949—DEGOLYER and MACNAUGHTON, "20th Century Petroleum Statistics."

† Total foreign except Russia and Sakhalin.

‡ Per cent American of total foreign except Russia and Sakhalin.

The first record of an American refining enterprise abroad indicates that in 1880 an independent American operator began running oil through a refinery he had built in Galicia, then part of Austria-Hungary, with equipment imported from the United States. From that date until the start of the First World War, American participation remained minor, although American-owned refineries are known to have been constructed prior to 1913 in Canada, Cuba, Mexico, Argentina, Japan, Rumania, Austria, Russia, France, and Germany. The total capacity of all these plants was probably between 35,000 and 40,000 bbl daily.

The first real American interest in foreign refining came with the wave of exploration and discovery of new crude supplies after the First World War. In the period between 1918 and 1939, substantial expenditures were made in Argentina, Venezuela, Peru, Dutch West Indies, Colombia, Mexico (enlargement of prewar facilities), England, France, Germany, Poland, Rumania (also expansion), Italy, Dutch East Indies, and Bahrein Island and to a minor extent in several smaller countries. While most of these plants were built to process local crudes, American companies were obligated in some areas lacking an indigenous supply to construct refineries running on imported crudes because of local government decrees which would otherwise have forced the companies out of their marketing business.

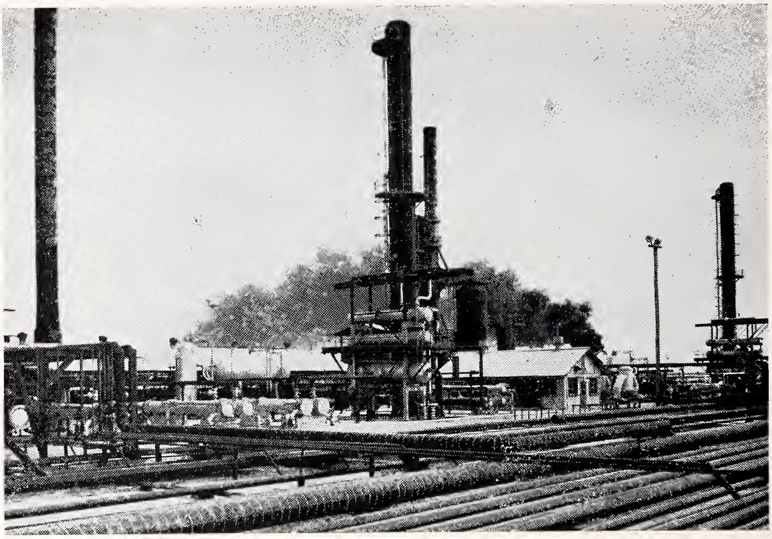

Fig. 10. View of the elaborate piping system at Aramco's Ras Tanura Refinery. The present capacity of the refinery, which is on the Persian Gulf Coast of Saudi Arabia, averages 140,000 bbl per day of gasoline, special fuel, diesel fuel, kerosene, and other petroleum products.

During the Second World War, when the need for oil products soared to new heights, there was a corresponding surge in refinery construction and expansion abroad. Much of the oil that was used to fuel the Allied war effort in the Atlantic Ocean and in Europe was produced in Venezuela and refined by an American company on the island of Aruba. Caribbean oil in large quantities was also used in the Pacific theater even after the refineries at Bahrein Island and Ras Tanura, in the Persian Gulf area, were in full operation. The Bahrein refinery, built with a daily capacity of 10,000 bbl in 1936, was expanded to 115,000 bbl a day in 1948. Construction of a 50,000 bbl a day refinery at Ras Tanura was started in 1944. Work was completed in 1945, and the refinery reported a capacity of 125,000 bbl a day in 1948.

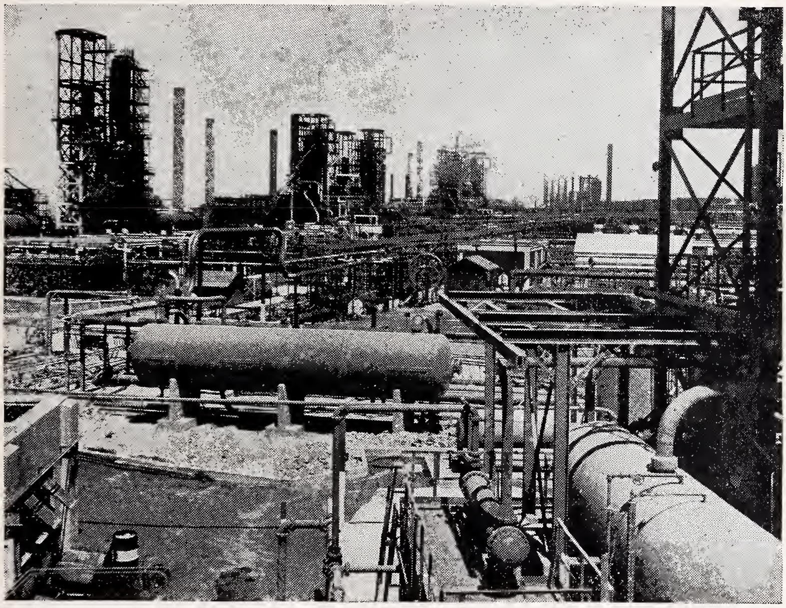

Fig. 11. Refinery at Aruba, Dutch West Indies.

The author does not wish to give the impression, at any time, that American-owned foreign refineries carried the lion's share of the war's refining load. Actually, at the height of the war, American-owned refineries in the Caribbean area accounted for slightly more than half of all refining there. In the Middle East, at the same time, American-owned companies provided about 10 per cent of the total volume of finished products from that area. The largest refinery in the world, for example, is the British-owned Abadan Refinery in Iran. It has a capacity of nearly 500,000 bbl a day.

World-wide demand for oil increased 24 per cent in the three years following the Second World War. To meet this demand refinery capacity almost everywhere has been expanded. American companies are either building or have plans to build important new refineries in Europe, South Africa, Venezuela, and Canada. Other refineries that were damaged during the war have been rebuild and, in many cases, enlarged.

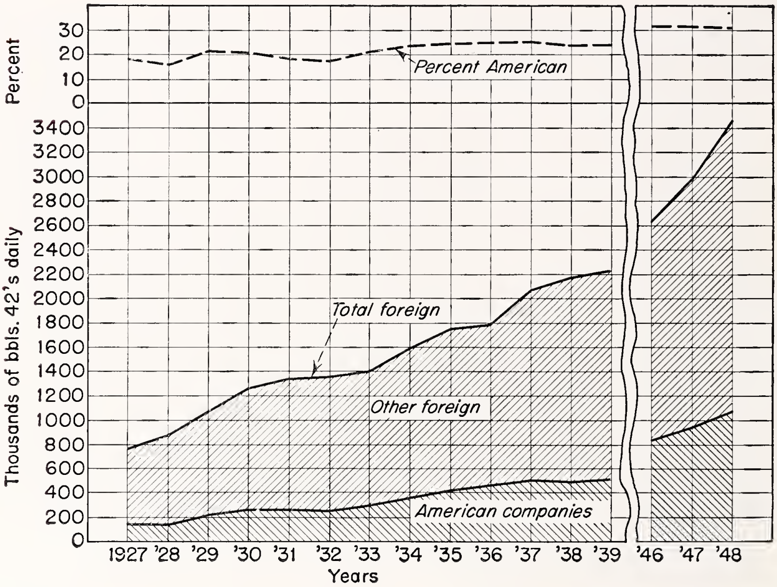

FIG. 12. Estimated foreign refinery runs of crude oil, showing quantity and percentage in American-owned.

The first complete record of foreign refinery runs (from a private source) is for 1927. In that year it was estimated that foreign refineries ran 750,000 bbl daily, of which American-owned plants accounted for 142,800 bbl daily, or approximately 19 per cent. Excluding Russia, American participation amounted to 23 per cent. By 1939 the American share in foreign refinery runs had increased to 23 per cent, and 31 per cent of the total excluding Russia.

The following comparison of foreign refinery runs and American participation shows the growth which has taken place between the years 1927 and 1948 (see also Fig. 12). In this table the figures for the recent war years are missing, because many foreign refineries came under Axis control and their records were destroyed, either by Allied bombing or by the managers themselves.

ESTIMATED CRUDE RUNS TO STILLS*
(Barrels of 42 U.S. gal daily)

Year	Foreign	Foreign except Russia	American companies	Per cent of foreign	American per cent of foreign except Russia
1927	757,100	613,300	142,800	18.9	23.3
1928	871,500	682,500	141,300	16.2	20.7
1929	1,064,500	840,000	219,600	20.6	26.1
1930	1,253,700	933,200	254,000	20.5	27.2
1931	1,314,900	916,700	268,200	18.9	27.1
1932	1,335,200	931,400	242,500	18.2	26.0
1933	1,369,700	1,022,800	286,400	20.6	28.0
1934	1,580,300	1,173,600	359,400	22.7	30.6
1935	1,726,900	1,304,700	405,800	23.5	31.1
1936	1,892,900	1,400,000	446,700	23.6	31.9
1937	2,078,500	1,563,200	307,400	24.4	32.5
1938	2,165,300	1,627,900	504,300	23.3	30.9
1939	2,242,500	1,669,000	524,800	23.4	31.4
1946	2,625	2,188	831	31.7	38.0
1947	2,989	2,472	948	31.7	38.3
1948	3,458	2,889	1,077	31.1	37.3

* From private sources.

MARKETING

Only broad trends in the American marketing position abroad are known, as detailed data on sales are not available.

We have already seen that it was in marketing that American oilmen first entered the foreign field. Records show that soon after the discovery of oil at the Drake well, a small shipment of American oil in casks was made to Belgium. In 1861 a small

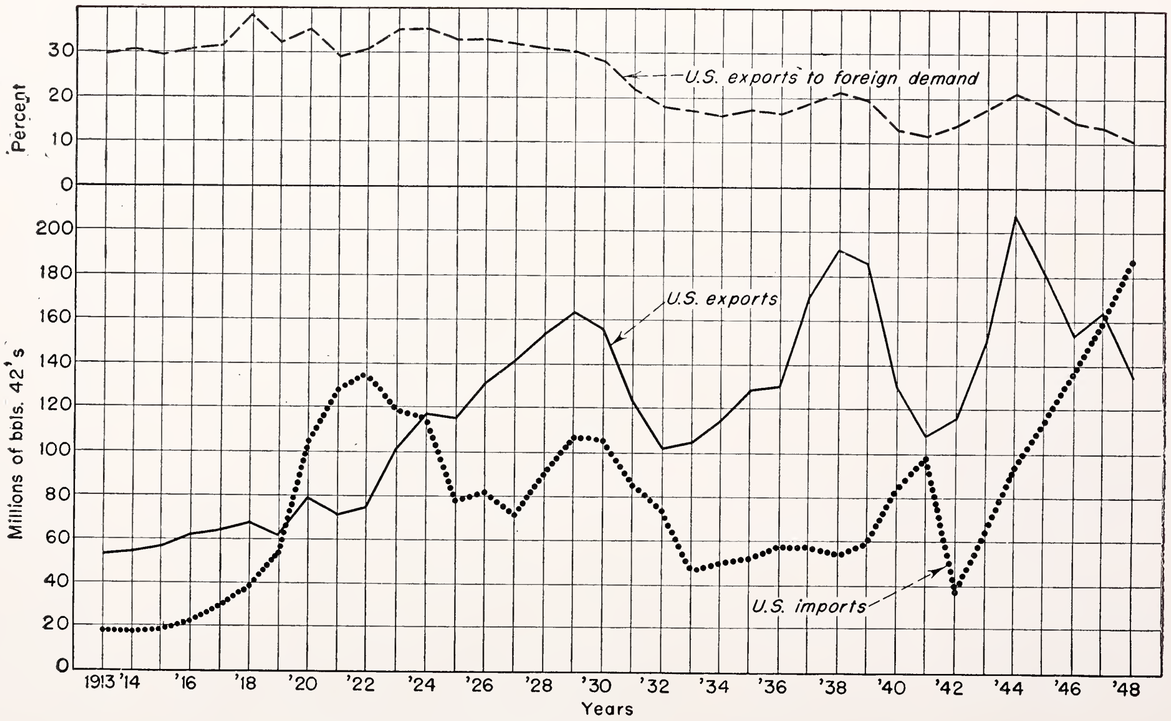

FIG. 13. United States imports and exports of crude oil and products.

sailing vessel was chartered to carry a 100 per cent oil cargo, also in casks, to London.

Exports from the United States continued to grow but up to the eighties were made largely to third parties in foreign countries. With the development of foreign oil production, however, intense competition developed in the foreign market, and American exporters, dependent on third-party purchasers, were faced with loss of foreign markets. The result was formation of foreign marketing units by American companies in the eighties and entry into direct marketing in all foreign consuming centers outside Russia—and even there American specialty products have been sold. Records of early times reflect active cooperation by American consuls and ministers to assure these American ventures an equal competitive opportunity in the various countries concerned (see Fig. 13 and Table 4).

Perhaps typical of the scope and far-flung nature of foreign marketing by United States interests around the turn of the century is the fact that the American supplier was so closely identified with oil in China that the Chinese expression for kerosene was taken from their name for the principal American marketer there.

United States oil exports in 1900, just prior to the first entry of Americans into foreign production, amounted to about 20 per cent of estimated total foreign consumption. Since part of this total undoubtedly went to third parties and American companies abroad also purchased some oil from foreign sources, the figure is not a dependable index to the American share in foreign markets for that year; but it does suggest that it was substantial.

With the development of production abroad by United States companies (the major share of which has been marketed abroad), the American companies were able to supplement United States exports. Therefore, not only has foreign development by American companies increased the world's over-all supply of oil, but, by supplying foreign markets from foreign sources, American companies have been able to decrease exports from the United States. This has resulted in a substantial saving of domestic oil for domestic use.

Table 4 shows how oil exports from the United States have decreased in proportion to foreign demand, except, of course, during the Second World War.

TABLE 4. EXPORTS AND IMPORTS OF CRUDE AND PRODUCTS BY THE UNITED STATES
(Thousands of barrels of 42 U.S. gal)

Year	United States exports	United States imports	Per cent United States exports to foreign demand
1913	52,251	18,231	29.8
1914	54,359	17,247	30.6
1915	56,449	18,192	29.7
1916	62,459	21,244	31.1
1917	64,503	31,563	32.1
1918	68,012	38,963	38.5
1919	63,848	54,198	32.9
1920	79,576	108,822	35.2
1921	71,652	128,792	29.1
1922	74,344	135,973	30.2
1923	101,981	99,653	35.1
1924	117,144	94,581	35.6
1925	113,834	78,200	33.3
1926	131,950	81,320	33.6
1927	141,649	71,736	33.1
1928	154,957	91,557	31.8
1929	163,120	108,710	30.3
1930	156,499	105,618	27.3
1931	124,394	86,087	22.1
1932	103,275	74,494	18.1
1933	106,727	45,394	17.5
1934	114,507	50,494	16.9
1935	128,987	52,635	17.8
1936	131,994	57,104	16.6
1937	172,834	57,157	19.6
1938	193,728	54,308	21.1
1939	188,959	59,060	19.8
1940	130,466	83,751	14.4
1941	108,830	97,142	11.8
1942	116,907	35,966	14.0
1943	149,957	63,412	17.2
1944	207,616	92,311	21.1
1945	182,983	113,619	18.7
1946	153,123	137,676	14.8
1947	164,477	159,389	13.7
1948	134,954	187,709	10.4

From the early thirties until about 1947, there was a great flow of oil from Latin America to Europe. Approximately 35 per cent of the oil used in Europe in 1948, for example, came from Venezuela, and about 40 per cent of it was produced by American companies. However, with the great development of Middle East oil fields, this movement of oil is changing. More and more of the Eastern Hemisphere's demands are being supplied from Eastern Hemisphere sources. Oil experts feel sure that, in time, practically all of Europe's oil, with the exception of a few specialty crudes and products, will come from the Middle East. Then Western Hemisphere oil will be consumed almost entirely within the Western Hemisphere, and the great transatlantic oil traffic will die down to a comparative trickle.

Since the Second World War American companies marketing American-developed oil (whether foreign or domestic) abroad have been faced with the serious problem of receiving payment. American companies are usually paid in dollars for what they sell, but there has been a serious shortage of dollar exchange in practically all foreign countries. As a result, many countries, especially those of western Europe, were hard pressed to obtain all the oil they needed during their rehabilitation period. Through the Marshall Plan and the Economic Cooperation Administration (ECA), dollar exchange for oil and other vital commodities has been made available to many of the western European nations, and they have been able to buy oil from American producers abroad. It is hoped, of course, that when ECA aid expires in 1952 the countries that benefited from that program will have their own currencies reestablished on a freely convertible basis, such as existed prior to the war.

TRANSPORTATION

The picture of petroleum transportation divides naturally into two segments, the pipe line, unique to the industry and essentially a plant facility; and all other means of transport, with the tank ship, of course, the paramount factor in this group.

The first petroleum pipe line was built in Pennsylvania in 1865, some six years after the Drake well, and from that beginning the network of pipe lines for which the United States is so famed grew rapidly. There has never been a comparable growth in any foreign area. Because of the inaccessibility of many important oil reserves, however, several major pipe lines have been built abroad to deliver landlocked oil to the seacoast. While no statistics are available, it is safe to say that American engineers have been responsible for the great majority of the work.

Chief among such lines are the two in Colombia already referred to, several in Venezuela, and the double line from Iraq to the Mediterranean. The two Colombian lines were built through jungle and swamp country presenting tremendous obstacles. One of these was the problem of crossing a mile-high branch of the Andes over largely uncharted country. A new Venezuelan line, completed in 1948, was the largest diameter pipe line in existence at that time. One stretch of it, 15 miles long, was laid under water.

The Iraq line, consisting of two parallel lines each 620 miles in length, was built by American engineers, it may be noted, despite the fact that the American participation in the area was only one-fourth. The double line crosses barren deserts and rugged mountains to the sea, and its completion was hailed as a major engineering achievement.

At the end of 1948, additional great pipe lines were being built in the Middle East area. Another double line, 16 in. in diameter, was being laid parallel to the Iraq line mentioned above. In addition, a 30-to 31-in. line was being pushed from Saudi Arabian fields to the Mediterranean, and even larger lines were being planned from Iranian and Kuwait fields to the same outlet.

Americans have also built lesser pipe lines in many oil areas. The largest diameter line in existence prior to the construction of the war-born "Big Inch" line in the United States was an American-owned 100-mile 16-in. line in eastern Venezuela.

Turning to the tank ship, the situation differs from other phases of the industry in the fact that most of these vessels, while an essential part of the petroleum industry, are actually owned and operated by shipping interests. Some 44 per cent of the approximately 1,600 ocean-going tank ships afloat at the outbreak of the Second World War were owned outside the petroleum industry, and the majority of tankers were under foreign flags. Some 10 to 15 per cent of these were American-owned, however, and this figure, added to American flag tonnage amounting to around 25 per cent of the world total, indicates that about 35 to 40 per cent of total world tanker tonnage was operated by Americans.

Allied tankers, since they were the only means of transporting oil to the Allied fighting forces overseas, became special targets for enemy submarines. During the Second World War 120 American-flag tankers were lost as a result of enemy action.

However, tankers were given a high priority in the shipbuilding yards. The United States Maritime Commission started a construction program in 1941, and 639 new ocean-going tankers were delivered between 1942 and 1946. Many of these were of the famous T-2 type, built according to a design evolved by the United States government and private interests, working together. All American tankers were operated, during the war, by a government agency. After the war those which had been privately owned were returned to their former owners. In addition, the government sold many of the T-2 tankers to private interests.

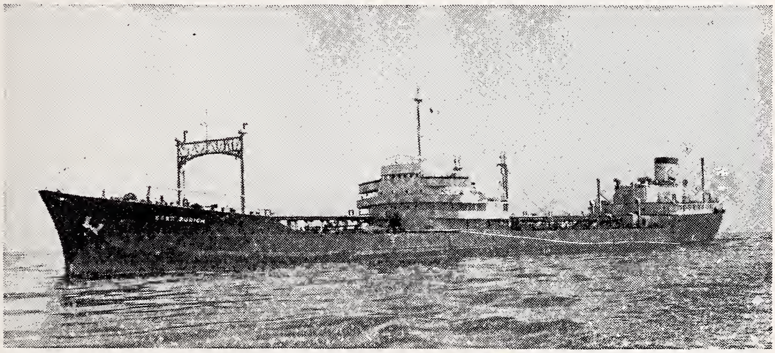

Fig. 14. Supertanker Esso Zurich waiting to pick up harbor pilot outside New York Harbor.

By the end of 1948 the world tanker fleet[1] amounted to about 2,000 ships of more than 1,000 gross tonnage. One-third of them were American-owned.

The Second World War

The preceding sections of this chapter have generally mentioned the importance of foreign oil resources to the Allies during the Second World War. However, in spite of all that has been published on this topic since the war, it is doubtful that the full importance of foreign petroleum operations is appreciated even today.

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[1] Including government-owned ships.

Foreign oil properties of both American companies as well as those of the other Allies were absolutely indispensable to winning the war. One of the principal reasons for this was the tanker situation. The operations of these properties provided shorter haul sources of supply than if the materials had been obtained from the United States. This resulted in meeting the military requirements, which otherwise would have been impossible even if more oil had been available from the United States.

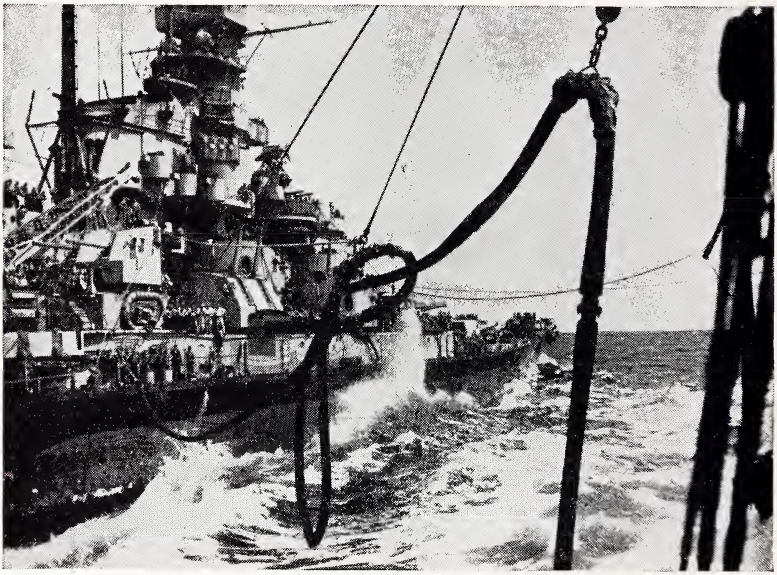

FIG. 15. Refueling at sea during the war. Fueling gear is hauled across the waves between a tanker and an Iowa-class battleship. The hose is looped to prevent if from dragging in the water and becoming fouled. (*U.S. Navy.*)

In the winter of 1941–1942, German submarines concentrated on the Atlantic tanker lanes. They patrolled the Florida Straits, the island passages between the Caribbean and the Atlantic, the east coast of the United States, the Gulf of St. Lawrence, and the approaches to the United Kingdom. In some places the customary sea lanes became so clogged with sunken tankers that navigation was impossible for all except the very smallest ships. By 1943, however, sufficient escort vessels were in operation to reduce the risks of submarine attack.

Even so, the principal petroleum problem of the Second World War was transportation. Coupled with the loss of tankers early in the war was the reduced effectiveness of the remaining tankers because of convoy operations and other protective measures, which sharply reduced turn-around time.

Therefore the primary basis for schedules of production, refining, and distribution was maximum over-all effectiveness in use of tankers. For example, supplies for India were allocated to the Persian Gulf refineries because that involved the shortest haul. Supplies for the central Pacific were obtained first from California, to the extent available, and second from the Caribbean area. The Caribbean area also represented a shorter haul source for all Atlantic and Pacific operations than the United States Gulf coast.

As the war progressed, the utilization and essentiality of foreign supply sources became more pronounced. Refinery projects in the Persian Gulf were rushed to completion, and their output was indispensable to the Pacific operations.

Even if transportation had not been a bottleneck, the availability of this foreign oil was extremely important. During the latter part of the war it furnished quantities of oil which could have been provided from the United States only by extreme rationing. Furthermore, such a move would have been seriously crippling to United States industrial productivity. It would have meant curtailing factory output and might have prolonged the war for a long time.

With strategically placed foreign resources it was possible to keep petroleum supplies flowing from several places out of range of enemy action, along the shortest tanker routes. The Second World War conclusively demonstrated the importance of foreign oil developments to our national security.

TECHNOLOGY

Many nationalities have contributed to the tremendously diversified modern technology of petroleum, but so great has been the part played by Americans in developing both the early and present know-how in finding, producing and utilizing oil that it is no exaggeration to say that modern petroleum technology is largely American.

American technical skill in petroleum exploration has long had universal recognition. Entirely aside from the activities of American-owned companies abroad, in all the far corners of the earth American geologists and geophysicists have worked under contract to foreign companies or governments, and several specialized American exploration companies have built up over a period of years a large business in foreign oil-exploration contracts for foreign interests.

It has not always been appreciated that in their foreign operations American oilmen generally have maintained technical standards fully abreast of practices at home. In fact some major advances in technique, particularly in the production field, have been intensively applied in both British and American-owned foreign fields before they became prevalent in the States. A prominent instance is the practice of pressure maintenance in oil fields, now receiving wide application in this country. One technique, gas repressuring, was conceived at home, and the general principles were outlined in the early twenties but did not find wide use until recent years. The opportunity to apply it first in fields abroad was taken by the engineers of one of the largest American operators abroad. As a result the oldest and perhaps still the best examples of this practice are found in American-owned fields in Sumatra and Peru.

Many other instances of up-to-date technique in American oil operations abroad could be cited in all phases of the industry from exploration to marketing. The foreign countries in which Americans operate share to the full in the continuing benefits of advances in petroleum technology for which the industry at home is so noted.

Economics

The American petroleum industry, both domestic and foreign, has been a significant factor in the economics of our foreign trade, (see Table 5 and Fig. 16). Petroleum exports accounted for 9 to 13 per cent of the total value of all United States merchandise exports from 1921 to the Second World War, ranging from 200 million to 550 million dollars. The tremendous demand for American goods during the war years occasioned a more than threefold growth in total exports from 1939 to 1944, from 3 billion to 14 billion dollars. Petroleum exports during this period showed a 150 per cent gain in value, and the share of the total dropped from about 12 per cent in 1939 to a wartime range of 4.0 to 6.8 per cent.

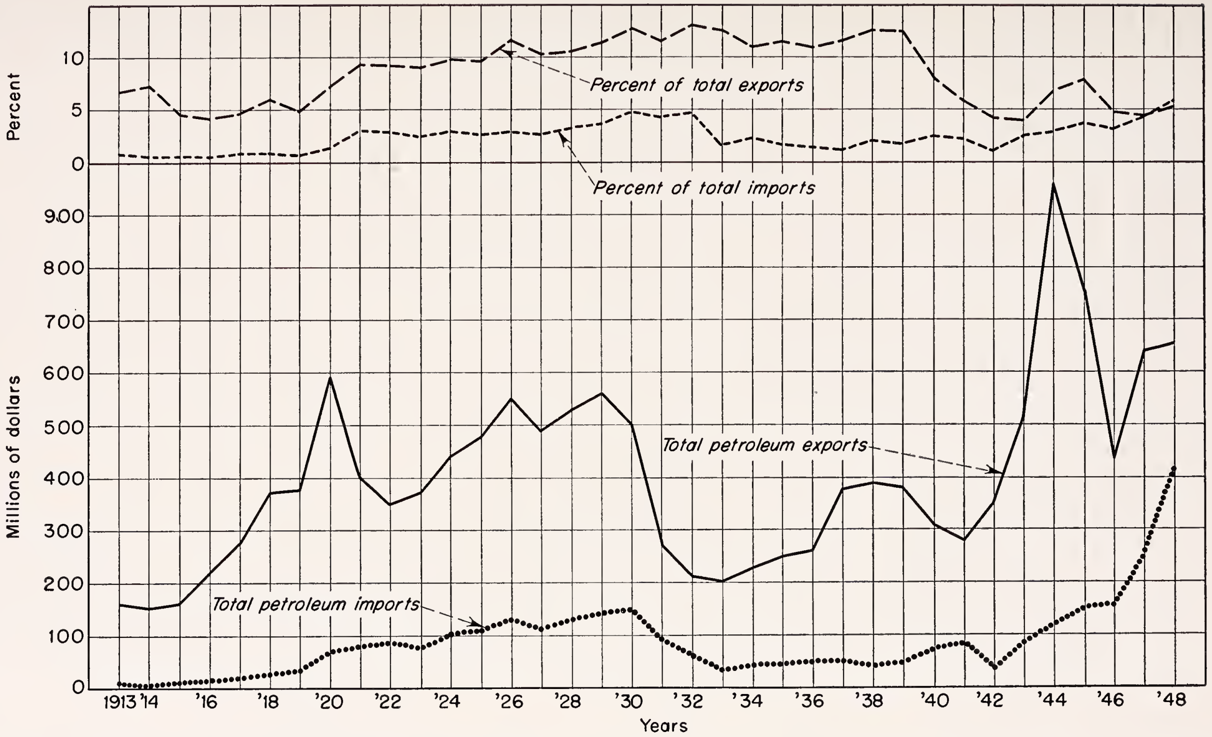

FIG. 16. Comparison of dollar value of United States imports and exports of crude oil and products with percentage to total.

TABLE 5. COMPARISON OF DOLLAR VALUE OF UNITED STATES EXPORTS AND UNITED STATES IMPORTS OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS (THOUSANDS OF DOLLARS); ALSO, PER CENT OF PETROLEUM IMPORTS AND EXPORTS TO TOTAL UNITED STATES IMPORTS AND EXPORTS*

Year	Value of total United States exports	Value of total petroleum exports	Per cent petroleum to total	Value of total United States imports	Value of total petroleum imports	Per cent petroleum to total
1913	2,448,288	160,584	6.6	1,813,008	12,997	0.7
1914	2,071,056	149,040	7.2	1,893,926	11,501	0.6
1915	3,493,236	159,792	4.6	1,674,170	10,564	0.6
1916	5,422,644	221,136	4.1	2,197,884	13,887	0.6
1917	6,169,620	275,148	4.5	2,659,355	20,605	0.8
1918	6,047,880	371,184	6.1	2,945,655	25,670	0.9
1919	7,749,816	377,124	4.9	3,904,365	31,441	0.8
1920	8,080,476	592,872	7.3	5,278,481	65,903	1.3
1921	4,378,932	401,232	9.2	2,509,148	78,844	3.1
1922	3,765,096	345,504	9.2	3,112,747	88,485	2.8
1923	4,090,716	366,792	9.0	3,792,066	78,713	2.1
1924	4,497,648	443,784	9.9	3,609,963	101,357	2.8
1925	4,818,720	474,024	9.8	4,226,589	107,694	2.6
1926	4,711,716	555,432	11.8	4,430,888	124,556	2.8
1927	4,758,864	486,768	10.2	4,184,742	113,434	2.7
1928	5,030,100	526,740	10.5	4,091,444	132,842	3.3
1929	5,157,084	562,116	10.9	4,399,361	143,557	3.3
1930	3,781,176	495,264	13.1	3,060,908	145,116	4.7
1931	2,377,980	271,284	11.4	2,090,635	92,741	4.4
1932	1,576,152	208,992	13.3	1,325,093	60,630	4.6
1933	1,647,216	200,688	12.2	1,449,559	25,693	1.8
1934	2,100,132	228,312	10.9	1,636,003	36,521	2.2
1935	2,243,076	251,124	11.2	2,038,905	37,346	1.8
1936	2,418,972	264,540	10.9	2,423,977	40,570	1.7
1937	3,298,932	378,132	11.5	3,009,852	44,586	1.5
1938	3,057,170	390,216	12.8	1,949,624	39,461	2.0
1939	3,123,343	385,068	12.3	2,276,099	43,541	1.9
1940	3,934,182	310,140	7.9	2,540,656	70,110	2.8
1941	5,019,877	284,653	5.7	3,221,954	82,455	2.6
1942	8,003,113	350,122	4.4	2,769,285	36,918	1.3
1943	12,841,542	516,762	4.0	3,389,951	85,223	2.5
1944	14,162,000	959,608	6.8	3,878,000	113,352	2.9
1945	9,585,000	753,084	7.9	4,086,000	151,958	3.7
1946	9,499,000	434,749	4.6	4,813,000	157,623	3.3
1947	14,279,000	641,642	4.5	5,650,000	250,459	4.4
1948	12,495,000	657,608	5.3	7,038,000	417,757	5.9

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* Sources: *Survey of Current Business, Foreign Commerce and Navigation. Statistical Abstract of United States.*

American direct investments abroad also have been of considerable significance in foreign trade. Studies by the U.S. Department of Commerce and the U.S. Treasury Department indicate that direct investments in 1929 constituted 52 per cent of the total long-term American investments abroad. By 1940 they were 60 per cent of the total, and in 1943 (the latest data available) they approximated 58 per cent.

Table 6 shows the American petroleum investments abroad by geographical breakdown in comparison with the total direct investments for the years 1929, 1936, and 1943. In 1943, American direct investments in the foreign petroleum industry were valued at about 1.4 billion dollars, almost 20 per cent of the total. The total direct investment totaled almost 7.4 billion dollars in 1943 and was just slightly below the 1929 level—petroleum investments, in the same period increased some 275 million dollars, or about 25 per cent.

Petroleum investments in the Western Hemisphere (except the United States) totaled about 780 million dollars, or some 55 per cent of the total. Venezuela, with 341 million dollars, represented almost 45 per cent of the Western Hemisphere total and almost a quarter of all petroleum investments abroad. The 161 million dollars invested in Canada was the second largest item in the foreign petroleum list and constituted almost 12 per cent of the total.

American investments in the European petroleum industry amounted to 370 million dollars and represented more than one-fourth of the foreign petroleum total. About two-thirds of the European total was accounted for by Germany (99.5 million dollars), United Kingdom (74.5 million dollars), Italy (35.4 million dollars), and France (34.4 million dollars). The remaining 17.5 per cent of American petroleum investments abroad was located principally in the Middle East, Indonesia, Union of South Africa, and India.

The potential influence of the oil industry on the economy of the various foreign countries is well illustrated by the case of Venezuela, an outstanding example of the favorable economic results derived from an open-door policy backed by equitable and stable laws. In 1943 some 530 million dollars was invested in the Venezuelan oil industry, of which American capital accounted for almost two-thirds. By 1947 the total investment had almost doubled to 1.1

Table 6. American Direct
(Thousands

Countries	1929				1936			
	Total direct investments	Petroleum			Total direct investments	Petroleum		
		Amount	Per cent total petroleum	Per cent total direct investments		Amount	Per cent total petroleum	Per cent total direct investments
Canada and Newfoundland	1,960,320	55,047	4.9	2.8	1,951,641	108,138	10.0	5.5
West Indies:								
Cuba	918,957	9,030	0.8	1.0	666,254	6,078	0.6	0.9
Other West Indies	134,794	25,562	2.3	18.9	86,877	22,715	2.1	26.1
Total West Indies	1,053,751	34,592	3.1	3.3	753,131	28,793	2.7	3.8
Mexico and Central America:								
Mexico	682,536	205,868	18.5	30.2	479,465	69,039	6.4	14.4
Other Central America	234,557	3,608	0.3	1.5	148,416	1,670	0.2	1.1
Total Mexico and Central America	917,093	209,476	18.8	22.8	627,881	70,709	6.6	11.3
South America:								
Argentina	331,819	29,811	2.7	9.0	*	*	....	....
Brazil	193,606	23,010	2.1	11.9	194,345	32,678	3.0	16.8
Columbia	123,994	55,835	5.0	45.0	107,549	58,577	5.5	54.5
Uruguay	27,904	3,260	0.3	11.7	*	*	....	....
Venezuela	232,538	226,171	20.2	97.3	186,266	174,430	16.3	93.6
Other South America	638,034	34,403	3.0	5.4	977,829	87,374	8.1	8.9
Total South America	1,547,895	372,490	33.3	24.1	1,465,989	353,059	32.9	24.1
Europe:								
Belgium	64,246	18,963	1.7	29.5	34,890	14,374	1.3	41.2
Denmark	15,824	6,006	0.5	38.0	13,778	5,474	0.5	39.7
France	145,009	25,108	2.2	17.3	145,683	40,463	3.8	27.8
Germany‡	216,514	35,270	3.2	16.3	227,817	49,993	4.7	21.9
Italy	113,216	25,903	2.3	22.9	*	*	....	....
Netherlands	43,224	12,144	1.1	28.1	18,836	6,824	0.6	36.2
Portugal	11,546	7,910	0.7	68.5	*	*	....	....
Spain	72,230	8,482	0.8	11.7	80,532	1,373	0.1	1.7
Sweden	*	*	....	....	25,493	8,272	0.8	32.4
Switzerland	16,804	6,634	0.6	39.5	*	*	....	....
United Kingdom	485,235	20,960	1.9	4.3	474,130	60,572	5.6	12.8
Other Europe§	168,905	63,591	5.7	37.6	223,793	87,599	8.2	39.1
Total Europe§	1,352,753	230,971	20.7	17.1	1,244,952	274,944	25.6	22.1
Asia:								
Arabia, Bahrein and Iran	*	*	....	....	17,780	17,453	1.6	98.2
British Malaya, French Indo-China and Siam	27,103	2,201	0.2	8.1	*	*	....	....
China	113,754	42,839	3.8	37.7	*	*	....	....
India	*	*	....	...	*	*	....	....
Cyprus, Iraq, Palestine, and Syria‖	7,050	1,875	0.2	26.6	29,605	20,911	2.0	70.6
Japan	60,700	8,007	0.7	13.3	*	*	....	....
Philippine Islands	79,935	10,381	0.9	13.0	*	*	....	....
Other Asia¶	105,998	48,628	4.4	45.9	369,608	108,599	10.1	29.4
Total Asia	394,540	114,001	10.2	28.9	416,993	146,963	13.7	35.2
Africa:								
British South Africa**	76,846	19,199	1.7	25.0	55,127	20,994	2.0	38.1
Egypt and Anglo-Egyptian Sudan††	*	*	....	....	*	*	....	....
Portuguese Africa	*	*	....	....	10,451	10,451	1.0	100.0
French Africa	*	*	....	....	*	*	....	....
Other Africa	25,383	12,293	1.1	48.4	27,116	8,072	0.7	29.8
Total Africa	102,229	31,492	2.8	30.8	92,694	39,517	3.7	42.6
Oceania, Australia, and New Zealand	149,154	68,856	6.2	46.2	111,027	42,986	4.0	38.7
International	....	....	....	....	26,190	8,962	0.8	34.3
Total world	7,477,735	1,116,925	100.0	14.9	6,690,498	1,074,071	100.0	16.1

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* Included in "Other."

† Source: *U.S. Dept. Commerce Trade Inf. Bull.* 731, American Direct Investments in 1929; American Direct Investments in Foreign Countries, 1936; American Direct Investments in Foreign Countries, 1940. Census of American-owned Assets in Foreign Countries," U.S., Treasury Department, Government Printing Office, Washington, D.C., 1943.

‡ Including Austria in 1940 and 1943.

INVESTMENT IN FOREIGN COUNTRIES†
of dollars)

1940				1943			
Total direct investments	Petroleum			Total direct investments	Petroleum		
	Amount	Per cent total petroleum	Per cent total direct investments		Amount	Per cent total petroleum	Per cent total direct investments
2,102,694	119,606	9.4	5.7	$1,727,700	$ 161,100	11.6	9.3
559,797	10,195	0.8	1.8	529,000	13,600	1.00	2.6
114,136	54,760	4.3	48.0	151,700	48,200	3.4	31.8
673,933	64,955	5.1	9.6	680,700	61,800	4.4	9.1
357,927	41,970	3.3	11.7	287,300	4,900	0.4	1.7
188,094	8,095	0.6	4.3	286,300	42,000	2.0	14.7
546,021	50,065	3.9	9.2	573,600	46,900	3.4	8.2
*	*			381,900	38,600	2.8	10.1
24,109	30,717	2.4	12.8	236,100	30,200	2.2	12.8
111,616	75,090	5.9	67.3	117,600	75,500	5.4	64.2
10,918	2,429	0.2	22.2	5,800	3,300	0.2	56.9
262,376	249,679	19.5	95.2	372,900	341,100	24.5	91.5
926,463	99,149	7.8	10.7	445,200	20,200	1.4	4.5
1,551,482	457,064	35.8	29.5	1,559,500	508,900	36.5	32.6
17,004	5,181	0.4	30.5	63,200	12,900	0.9	20.4
19,691	9,626	0.7	48.9	22,100	10,900	0.8	49.3
117,199	42,682	3.3	36.4	171,200	34,400	2.5	20.1
349,399	57,391	4.5	16.4	554,000	99,500	7.2	18.0
75,493	37,759	3.0	50.0	90,000	35,400	2.5	39.3
18,167	4,124	0.3	22.7	59,700	8,400	0.6	14.1
7,050	3,779	0.3	53.6	14,100	*	*	*
73,396	1,890	0.1	2.6	124,300	1,700	0.1	1.4
26,361	7,181	0.6	27.2	32,900	9,800	0.7	29.8
23,852	2,546	0.2	10.7	45,100	3,000	0.2	6.7
540,694	71,257	5.6	13.2	520,200	74,500	5.4	14.3
152,059	62,105	4.9	40.8	350,200	79,400	5.7	22.7
1,420,365	305,521	23.9	21.5	2,047,000	369,900	26.6	18.1
57,234	56,266	4.4	98.3	50,700	48,800	3.5	96.2
*	*			31,300	*	*	*
*	*			87,100	13,400	1.0	15.4
48,775	19,478	1.5	39.9	65,300	20,400	1.4	31.2
*	*			16,800	*	*	*
*	*			43,700	6,900	0.5	15.8
*	*			99,300	9,600	0.7	9.7
315,936	101,138	7.9	32.0	112,800	51,700	3.7	45.8
421,945	176,882	13.8	41.9	507,000	150,800	10.8	29.7
72,901	24,427	1.9	35.5	19,100	*	*	*
22,753	9,395	0.7	41.3	21,000	8,300	0.6	39.7
*	*			2,200	1,200	0.1	54.5
9,789	8,937	0.7	91.3	500	—	—	—
25,630	7,176	0.6	28.0	97,400	35,800	2.6	36.8
131,073	49,935	3.9	38.1	140,200	45,300	3.3	32.3
120,232	49,365	3.9	41.1	129,300	48,000	3.4	37.2
32,597	3,780	0.3	11.6	—	—	—	—
7,000,342	1,277,173	100.0	18.2	$7,365,000	$1,392,700	100.0	18.9

§ Including Turkey in 1929.
‖ Including Iraq in 1929.
¶ Including Turkey in 1936 and 1940 and 1943.
** Including other British Africa in 1929.
†† Including Anglo-Egyptian Sudan in 1943.

billion dollars, and (although no accurate information is available) it might be assumed that the American share, proportionately the same as in 1943, was in the neighborhood of some 650 million dollars.

Venezuela is the world's second largest crude producer (close to a half a billion barrels in 1948) and the largest petroleum exporter. Petroleum exports account for about 95 per cent of the country's total merchandise shipments, and without them it would have been impossible to finance the volume of imports needed to sustain her economy. The sale of foreign exchange in Venezuela by the oil companies covers wages, taxes, and other producing costs within the country and in addition leaves a substantial net credit before gold and capital movements take place.

In 1947, the Venezuelan government imposed extraordinary taxes on the oil industry in order to effect a fifty-fifty share in petroleum profits. Government income from the industry has shown a phenomenal growth from 1943 to 1948, increasing from about 58 million dollars to over 411 million dollars. These 1948 receipts (provisional) represented in excess of 70 per cent of the total government income in 1948 compared with about 53 per cent in 1943. In addition to these payments the oil companies have made many indirect contributions to the Venezuelan economy, such as accelerated industrialization, expanded employment, road construction, port works, schools, and hospitals.

In other Latin-American countries petroleum has also contributed substantially to economic development, particularly in Peru, Colombia, and Mexico. In Peru, where approximately 80 per cent of petroleum output is produced by an American company, petroleum and its products constituted about 30 per cent of the value of the country's total merchandise exports in the period from 1935 to 1941.

Although petroleum has provided a somewhat smaller percentage of the total merchandise exports of Colombia, the narrow margin by which her total exports normally exceed her imports emphasizes the importance of the petroleum trade. Eliminating petroleum exports, Colombia would have found it necessary to curtail the volume of her imports in each year of the 1935 to 1941 period.

The Middle East has become the second most important center of American-financed oil operations in the foreign areas. Opera-

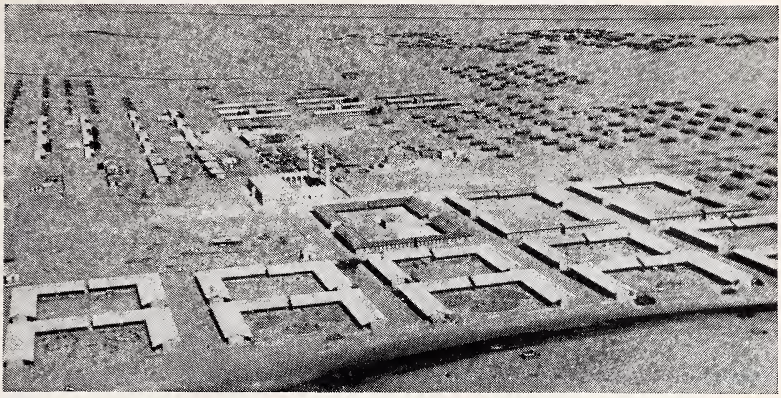

FIG. 17. Aerial view of camp at Dhahran, Saudi Arabia. Arab employees of Aramco are housed in these modern brick dormitories, which Aramco is rapidly building to replace the barrasti huts visible in the background. The building with twin towers is an Arab mosque.

tions in this area call for large capital investments, which bid fair to become as important to these countries as is the case in Venezuela. Every effort is being made to promote the welfare and education of the inhabitants and to introduce American techniques for the improvement of the general economy. Industrialization

FIG. 18. Saudi Arabian employees of Aramco line up to receive awards for ten years of service with the company. Aramco presents all of its employees with service awards for each five years of work with the company.

has been given a good start with the operation of refineries, pipe lines, railroads, port facilities, etc., necessary for the companies' own operations. In addition oil companies maintain industrial and primary schools, modern hospitals, and recreational and housing facilities for both foreign and native employees.

Social Effects

Except for a very few instances the major oil deposits abroad have been developed in sparsely populated, often all but inaccessible regions—many of them tropical. As reconnaissance work is completed, roads are needed, and vast areas of the countryside must be cleared for the material to be used in the oil development. Care for the health of employees, both national and foreign, is a hallmark of American oil ventures in these areas, and medical work is of paramount importance as operations expand.

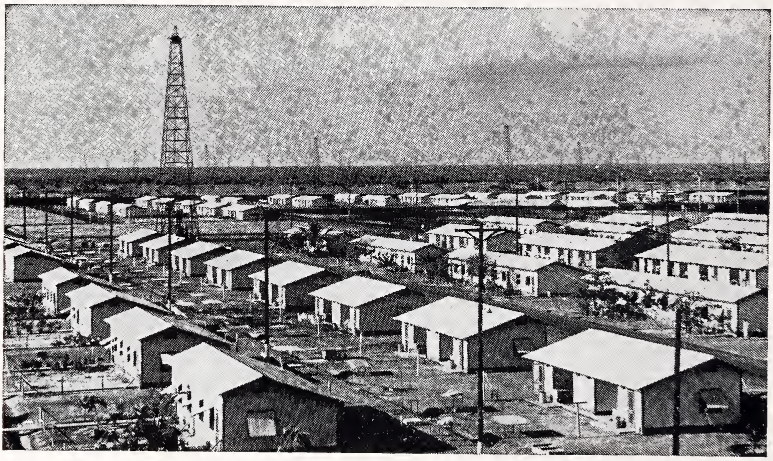

Fig. 19. Workers camp at Lagunillas, Western Venezuela.

The program for the control of endemic diseases such as malaria, dysentery, and hookworm commences before the spudding operation of a well. In the establishment of a camp, sanitation and cleanliness are the foundations upon which medical programs have been constructed. The contributions which American petroleum companies have made to the steady improvement in health conditions in areas where they have been operating have received very favorable comment from many of the local health authorities in foreign countries.

The record in Venezuela is interesting and informative. When the oil companies entered Venezuela some twenty-five years ago, the population, because of the agricultural nature of the country, was untrained in the mechanical trades and hence not well equipped to participate in the early stages of development. The companies embarked on educational and training programs, and the Venezuelan employees showed marked aptitude for mechanical training. As this vocational education developed, nationals were employed to an increasing extent, and today every well is handled efficiently by Venezuelan drilling crews; Venezuelans are also taking major responsibility in the conduct of the refining and trans-

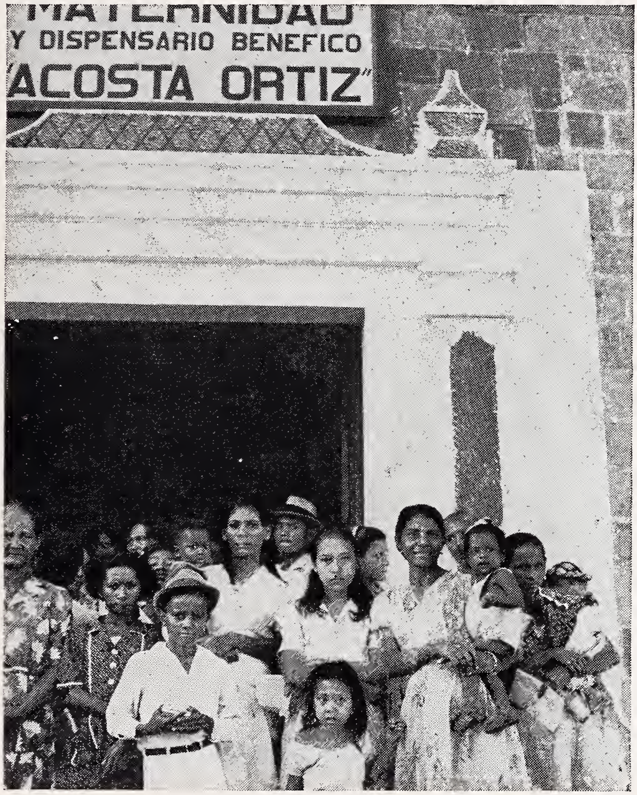

Fig. 20. Maternity hospital in village of Caripito, built partly by Creole Petroleum Corporation.

portation phases of the industry. Training in supervisory work and in clerical and stenographic fields has also been carried on widely.

Outstanding students in the technical schools of the country have been given scholarships to continue their studies in United States schools, and many of the important departments of the petroleum industry are now headed by Venezuelans.

The picture in Colombia, Peru, Argentina, Aruba, the Dutch East Indies, the Middle East, and other areas is generally similar to that described for Venezuela, varying only in scope as determined by the nature of the areas and degree of development.

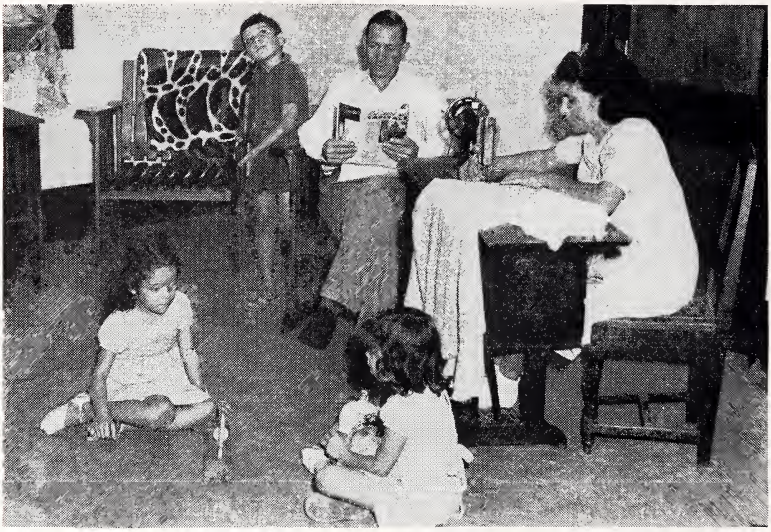

Fig. 21. Venezuelan oil worker and family in Creole's Caripito camp home built by oil company.

Many American companies abroad have organized various plans among local employees for systematic saving and employee-sponsored credit unions, through which employees can obtain financial aid at a reasonable rate of interest.

Along with specialized social and educational work is the broad background of widespread employment and opportunity for economic advancement brought by oil developments. American oil companies abroad are noted for favorable wage levels, and the overall influence of their operations improved standards of living

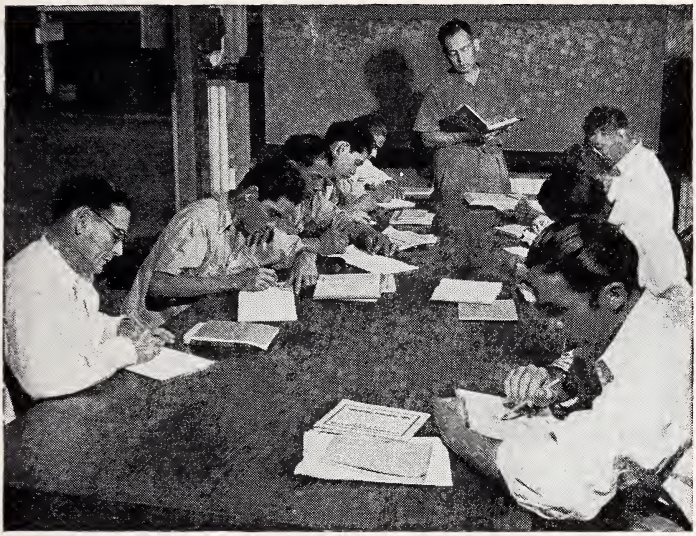

Fig. 22. Venezuela. Primary education class for workers held in the marine repair shop after working hours, La Salina. Most of these men have never been to school before.

through the increase in national wealth accruing from their activities.

Government and Industry Policy

During the past half century official policy and public feeling toward petroleum and its development have undergone many

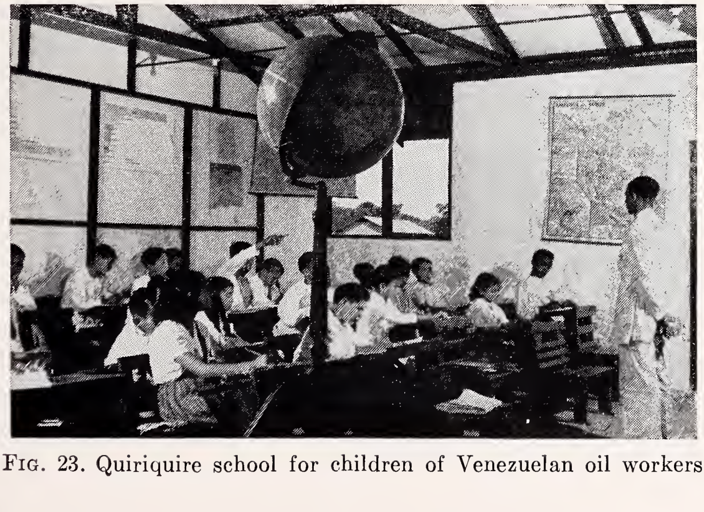

Fig. 23. Quiriquire school for children of Venezuelan oil workers.

changes. For a while, during the early years, governments in many countries refused to be bothered with petroleum problems. The public, on the other hand, regarded oil as a "get rich quick" affair. It was all right for those who didn't mind losing their shirts, but the nonspeculative individual paid little attention to oil unless some company wanted to drill on his land.

However, as oil became the prime motive power for automobiles and for ships and a source of heat for homes and steam boilers in factories, its stature in respect to public interest grew. It became an important factor in international trade, and it soon became an even more important factor in international destiny. Nations without petroleum resources within their own borders realized that, if they did not have guaranteed oil supplies, they were at a disadvantage compared with nations that did.

This led to a reexamination of subsoil rights and the passage of laws concerning the development of oil resources. Some countries, notably the United States, encouraged the development of petroleum by any individual or company that desired to go into the business. Other nations took the opposite path and retained oil rights in their own governments. But even these policies have changed during the years.

In the period following the First World War the United States adopted a very broad oil policy, especially as American oil interests abroad were concerned. A traditional basis of our foreign policy has always been support for the open door in commerce, essentially a matter of securing the same opportunities for American business abroad as those enjoyed by nationals of other countries—in effect, endeavoring to obtain only the same equality of commercial opportunity in other countries as that afforded to foreigners in the United States.

In the field of petroleum the pursuit of this policy encounters problems not found in dealing with most commodities. Subsoil mineral rights in most foreign countries belong to the state; all negotiations by Americans seeking to develop these resources therefore must be carried on with government rather than with private interests. Temporary political expediency, diplomatic pressure from other interested governments, and on occasion the tendency to yield blanket or exclusive concessions to one's own nationals—all may react (and frequently have reacted) against equitable opportunity for Americans.

With the First World War, as we have said, oil resources became of major importance to the nations of the world. The British and Netherlands governments, in particular, were concerned over petroleum. They tended to give strong preference to their own nationals in petroleum exploration within their empires and obtained spheres of influence in other sovereign countries.

The interest of the United States government in these trends was sharpened by an oil-shortage scare at home after the First World War. Over a period of a decade after the war the government repeatedly urged American oilmen to develop resources abroad, offering strong diplomatic support wherever inequitable barriers were imposed. As early as 1920 the Democratic platform was very positive in its urgings to American citizens to acquire and develop oil properties in foreign lands. Plank 9 stated:

"The Democratic Party recognizes the importance of the acquisition by Americans of additional sources of supply of petroleum and other minerals and declares that such acquisition both at home and abroad should be fostered and encouraged."

This same general policy was reiterated during the Harding and Coolidge administrations, and the American oil companies responded. Between 1918 and 1928, large oil reserves in Latin America, the Middle East, and the Dutch East Indies were developed by American oilmen. In the case of Latin America, especially Venezuela, the oil companies were able to negotiate their own contracts—and it is a tribute to the joint vision of the countries and the companies that those contracts which are still in existence have remained so firm and fair. In the other two areas, however, it is doubtful that Americans would have obtained any foothold whatsoever without government assistance.

The depression of the thirties forced the United States government to focus most of its attention on domestic problems, and interest in developments abroad lagged. Even so, prior to the Second World War, American companies were able to secure new concessions in foreign areas, notably in Bahrein, Kuwait, Saudi Arabia, and Egypt.

Wherever American oil companies have gone, as we have seen, they have benefited the countries in which they operate. Even so, there are still several places which prohibit the operations of foreign companies—not only Americans—within their borders. It is not that they do not need oil, because they do. Nor is it because they do not have oil potentialities. Their earth may be rich in it. But their laws relative to its production are so discriminatory or so restrictive that it is virtually impossible for private capital from the United States to undertake the risks always inherent in searching for oil.

However, with the exception of countries that have passed behind the Iron Curtain since the Second World War, there is evidence that many countries which for years have excluded American oil participation are beginning to relax their laws. They have seen what has happened in Venezuela and Saudi Arabia, on the one hand, and in Mexico on the other. Within the next few years it is entirely possible that the ring of American oil-drilling rigs will be heard in places which have never known that sound before.

For almost a century of direct and indirect participation in foreign petroleum business, American oilmen have sought only an equitable basis for operation, with reasonable assurance of local government integrity and adherence to agreements. The record shows clearly that they have sought neither monopoly nor special advantages. Without seeking subsidy or government aid other than diplomatic support in dealing with foreign governments, they have made a proud record.

Much of this record, since 1930, has been brought about by the enlightened policies of the industry itself. Foremost spokesman for the industry at present is the National Petroleum Council, a group of leading oilmen, appointed by the government and acting in cooperation with it. This organization has expressed the industry's desires and obligations in regard to future foreign operations.

Basically, what the American petroleum companies seek with regard to operations abroad is an "even break." They want no special privileges. They do desire access to world oil resources, on equal terms with others, and stable agreements.

The National Petroleum Council, in its recommendations for A National Oil Policy for the United States, spells this out as follows:

"1. The participation of United States nationals in the development of world oil resources is in the interest of all nations and essential to our national security.

"2. An effective oil policy should encourage access by our nationals to world resources on equal terms with other nationals, and stable agreements between foreign governments and private industry on a basis which will promote development by free-enterprise methods.

"3. The Federal government should encourage foreign oil development by American nationals by efforts directed through diplomatic channels to reduce political risks involved in such foreign operations and by permitting United States citizens to operate abroad in conformity with the laws and customs of other countries."

Conclusion

With only about 12 per cent of the world's potential oil land, the United States has produced over 63 per cent of the world's total oil supply to date. No one has seriously questioned the fact that this impressive picture is founded on the opportunity provided in this country for free competitive play of individual initiative and enterprise. It should not be surprising, then, that American oilmen overseas have looked for no more than similar freedom to win oil from the earth and make it more available to the countries concerned and for the future welfare of the United States.

It has often been remarked that American oilmen seem to have developed a nose for oil—that both at home and abroad they are often more successful than any other peoples in the search for oil. Whatever the validity of this idea, it is interesting to note that those countries which have welcomed American oilmen and most nearly provided the atmosphere of free enterprise seem to have received the highest realization on their potential oil resources.

The future of oil in the world is today a prime subject of thought and international discussion. Our own government is seeking, with the help of the industry, to maintain a national oil policy that will safeguard our national interest and provide a base of continuity and stability on which American oilmen may depend in planning their operations abroad. Americans have been a key factor in the development of the world's oil resources. As a result the world has greatly benefited by American ingenuity and aggressiveness. It is unthinkable that Americans should not continue to contribute to foreign oil production with its attendant benefits to all civilization.

Chapter IV

CONSERVATION OF OUR OIL AND GAS RESOURCES

By HIRAM M. DOW

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The achievements in the conservation of oil and gas in the last twenty years constitute a remarkable chapter in the history of cooperative effort. The executive, the technologist, the engineer, the economist, the lawyer, the legislator, and the conservation administrator have all combined their knowledge, ingenuity, and energy in devising and getting under way procedures and practices resulting in greatly increased ultimate recoveries of oil and gas, their production at relatively lower cost, and the accumulation of reserves adequate to meet civilian needs and the demand for national security.

It is well known to all oilmen that the ultimate recovery of oil has been greatly increased through cooperative practices and conservation efforts now employed throughout all of the oil fields of this country.

Millions of dollars have been spent in the building and equipping of laboratories, in the training of research specialists in field and laboratory experimentation, in the construction of cycling and repressuring plants, in gas-injection and water-injection projects. The spirit with which the petroleum industry has tackled the problems of conservation is indeed a tribute to its progressiveness. As a result of scientific study, methods have been evolved and put into operation whereby as much as 80 per cent of the oil will be recovered from many fields. A few decades ago it was not unusual to recover only about 20 per cent of the oil in a new field.

New methods and new theories will continue to be presented and tried out as long as oil and gas are produced, and it will be the constant and increasing responsibility of the oil industry and of the oil-producing states, through the medium of the Interstate Oil Compact Commission, to keep abreast of these rapidly developing scientific programs. Of course, the oil operators will keep abreast of the industry's own progress because they lead in developing conservation programs, but, particularly, will it be the responsibility of the Interstate Oil Compact Commission to see to it that the proper authorities in the oil- and gas-producing states are kept fully informed.

The day the industry realized that an oil or gas reservoir is a physical unit and must be controlled as such marked the beginning of true conservation. When only the well was considered, it was impossible to fix the true interrelation among all the wells producing from a common pool. It is only by control of the reservoir as a whole that the natural energy originating in the reservoir can be most efficiently utilized to obtain the maximum amount of economically recoverable oil from each pool.

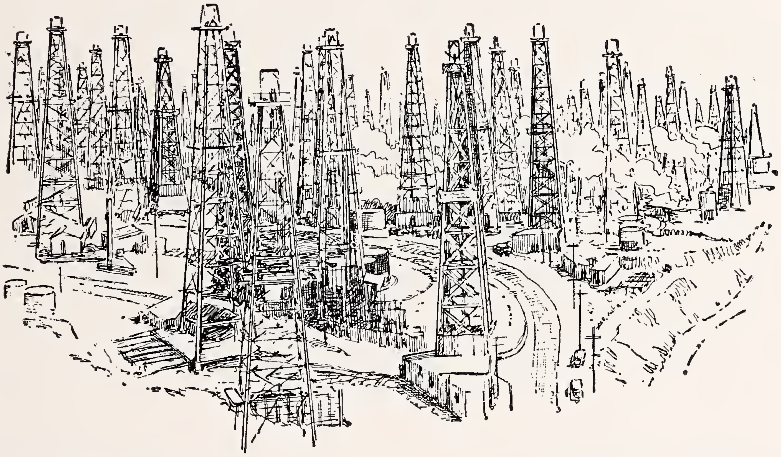

Fig. 24. An old-time oil field crowded with the derricks of unnecessary wells.

Underground forces existing in the earth must be employed to control the movement of oil in the reservoir. Underground energy resides, not in the oil itself, but in the water or gas associated with the oil, including free gas and gas dissolved with oil, and in the universal flow of gravity. It is elementary that the production of oil and water must be controlled to permit proper completion and repair of wells, through utilizing the forces of nature to bring the oil to the surface and the action of water or gas displacing the oil taken from the formation throughout the entire reservoir.

In controlling the rate of flow to prevent dissipation of natural energy, two factors predominate: (1) rate of production from the field as a whole as well as from parts of it; (2) use of an adequate number of properly located wells to produce the desired quantity of oil.

The large-scale movement of underground fluids is not rapid. Hence, a controlled production rate is necessary in water-drive fields to maintain the reservoir pressure, and in volumetric-controlled fields it is necessary to prevent gas channeling and permit proper control of gas-oil ratios. The restriction of the rate of production is, therefore, the first and most important step in any conservation program. Each pool differs in many physical characteristics, making it necessary to study the individual pool to determine, for the peculiar and unique conditions encountered, the restrictions needed for the particular field in order to obtain the maximum recovery.

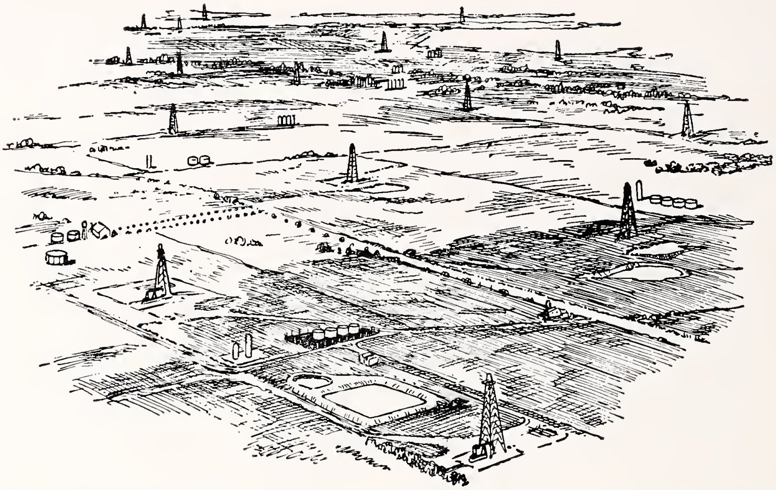

FIG. 25. Conservation begins with the orderly development of the field. Such development conserves materials, capital, and labor; and it means lower production costs.

Control of the rate of production involves also proper and equitable distribution of the controlled rate. Production must be distributed over the reservoir so as to avoid excessive localized withdrawals. Allocation among the separate leaseholders in a common pool must be fair and equitable to provide each operator an opportunity equal to that afforded all other operators to produce the equivalent of the recoverable oil underlying his property.

The problems of oil and gas conservation are unique, and the methods employed are likewise unique. This, of course, arises from the characteristics of oil and gas and the nature of their occurrence, behavior, and production. When a well is sunk into a reservoir and oil and gas are produced therefrom, because of the pressure under which they exist in the reservoir they move underground to the low-pressure area at the bottom of the well, sometimes draining for great distances regardless of property lines. This fact is of great significance, for the oil produced by a well belongs to the owner of the land on which the well is located. When brought to the surface, gas dissipates and oil rapidly evaporates if not held in closed containers. These characteristics create a problem in regard to storage, use, and waste.

It is not economically practicable to store gas in substantial quantities for long periods of time. When produced it must either be returned to the reservoir or moved directly to market for immediate use or be dissipated to the air or to the torch. The storage of oil above ground is feasible but costly and wasteful for large quantities. The industry has learned through bitter experience that the ideal place to store oil is in its natural reservoirs underground, except for reasonable working stocks needed in tanks. To prevent waste, therefore, oil and gas should be produced only in response to market demand.

The basic rule of property is that the owner of land owns everything beneath his surface property line. As a practical matter, however, there is a subsidiary rule of property under which when he sinks a well on his land and produces oil or gas through such well he has title to that product, even though such oil or gas may have been drained into his well from underneath a tract of land belonging to another. As a consequence, prior to effective conservation methods, when oil or gas was discovered a competitive race ensued between the separate owners of lands for maximum recovery. This situation led to close drilling of wells and production at high rates. Each operator tended to produce as rapidly as possible in order to secure maximum quantities for himself at the expense of his neighbors. The demands of the market were ignored. Unlike the farmer, manufacturer, or miner, the oil producer is not free, in the absence of agreement with other producers or regulations by the states, to limit supply in response to market conditions. He must either produce as fast as his neighbor or lose his oil to another.

These conditions resulted in the drilling of great numbers of useless wells in the early oil fields. Such development and open-flow production led to (1) profligate waste of great quantities of otherwise recoverable oil underground; (2) dissipation of gas; (3) loss and waste of oil above ground by evaporation. The reservoir energy was early dissipated. Wells were placed on the pump, or other artificial means of lifting were employed, and as a result expensive secondary methods of recovery became necessary.

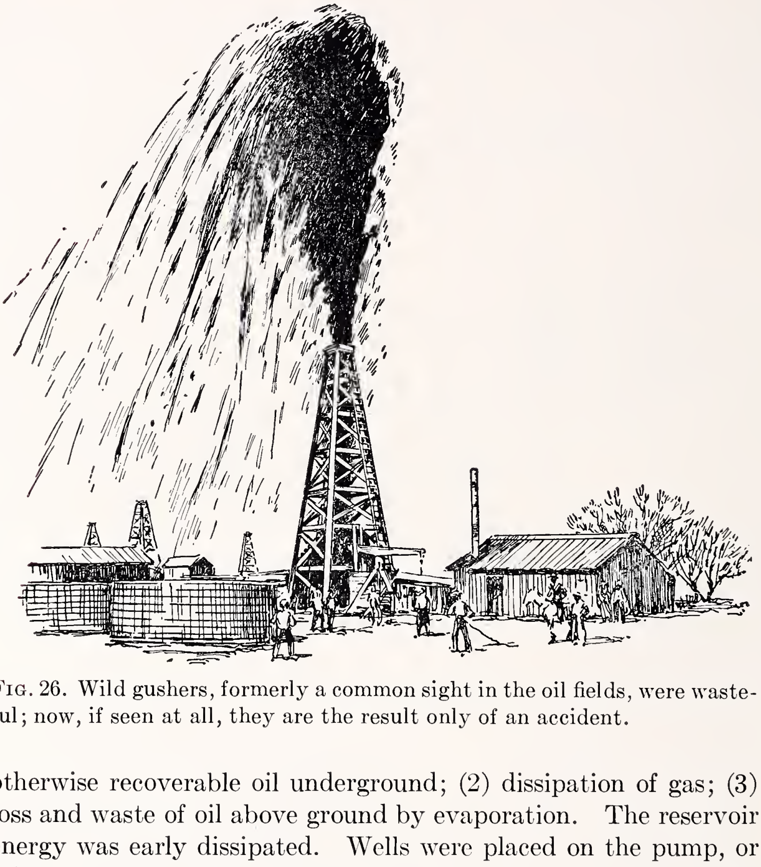

FIG. 26. Wild gushers, formerly a common sight in the oil fields, were wasteful; now, if seen at all, they are the result only of an accident.

Such methods of operation led to recurring periods of feast, when the markets were flooded with low-price oil, and famine, when shortages occurred and prices rose to indordinate levels. Discoveries often came in cycles, with rapid development and flush production from new fields leading to a nation-wide surplus of oil.

Conservation is basically a matter of controlling the rate of production to obtain maximum recovery of oil from the reservoir and to avoid waste aboveground. If waste is to be prevented underground, it is necessary to produce the oil and gas at rates which will fully utilize the reservoir energy, permitting the oil to be flushed uniformly and fully from the reservoir. If waste is to be prevented aboveground, the rate of production must respond to and not exceed the market demand. Production must be limited to the market demand or the maximum rate which a field can produce without waste, whichever is lower.

It is only in the last twenty years that it has become generally recognized that conservation is accomplished basically by proper control of the rate of production. In the early days the economic evils of the feasts of overproduction and the famines of underproduction were viewed as unavoidable. Very little was known by the petroleum industry in general of the nature and character of oil reservoirs, of the behavior of oil, gas, and water in the reservoir, of the basic principles of reservoir pressure, or of operating oil fields so as to utilize effectively over a long period of time the energies of the pool itself in lifting oil to the surface. Relatively little research in these areas of knowledge had been undertaken. Aboveground waste was understood in part, but few had any concept of the nature or extent of underground waste incident to the open-flow production method.

The conservation of oil and gas resources has passed through a long and painful process of trial and error. During that time there has been a steady progress from the early-day wasteful method when little was known of the value of reservoir energy to the present known and established engineering principles applied to the discovery, development, and operation of oil and gas pools.

It was the firm belief of the early-day operators that an oil well should not be restricted in its flow, that to shut in a well after it had been flowing was the worst possible practice, which would result in the ruination of the well. This concept produced many wasteful practices such as occurred in the development of the Cushing field in Oklahoma, where oil ran down the ravines and was held in earthen pits rather than restrict the flow from the wells. This resulted in waste of oil aboveground, waste of energy and recoverable oil underground, and economic waste since these first fields were produced at a rate greater than the market could absorb and the price of oil was driven down to a ridiculously low figure.

Gradually the geologist, the engineer, and practical oil operators began to realize and understand the physical conditions under which oil and gas are accummulated in the earth and the physical laws which govern the production of oil and gas. Only in comparatively recent years has it been realized that there are both effective and ineffective ways of utilizing underground energy and that by its proper use and control it is possible to recover a great amount of oil from a given pool.

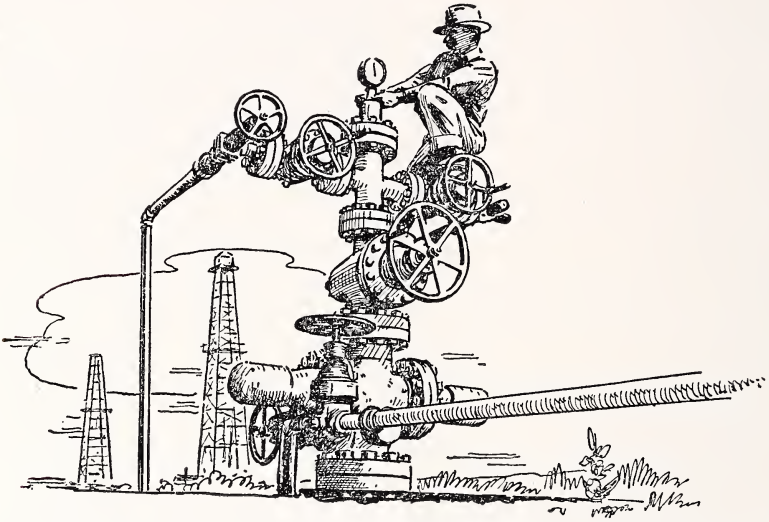

Fig. 27. Why the wild gusher is a thing of the past—the "Christmas tree." Thousands of pounds of pressure require the heaviest valves and fittings to control and safeguard the deep wells of today.

The energy available underground exists, not in the oil itself, but in the water and gas associated with the oil. It is thus self-evident that the production of gas and water must be controlled, since the recovery of the maximum amount of oil from a pool is dependent upon how this energy is used.

To gain an understanding of the principles of oil and gas conservation it is necessary to discuss for a moment the nature and behavior of oil reservoirs.

An oil reservoir consists of a porous and permeable rock, the pores of which contain oil and gas under pressure. The impervious bed overlying the oil zone serves to trap the oil in the productive sand. Below or at the edges of the oil accumulation, the same sand or lime body is usually found to contain salt water.

Normally, under reservoir pressure there is gas dissolved in the oil, and any gas present in excess of that which can be held in the solution of the oil under prevailing pressure and temperature will be found in the higher portions of the sand's body in the form of a gas cap.

The original relationship of the contents of an oil reservoir is therefore one of free gas, if present, occupying the crest of the structure, oil underlying the gas, and water below the oil. This zonal arrangement is due to the gradual segregation of the fluids throughout geological time.

The gas dissolved in reservoir oil reduces the viscosity and makes the oil much more fluid. When gas has been released from the solution by permitting the reservoir pressure to drop, the oil cannot move so freely to the well and more oil is left unrecovered in the sand.

It is impossible to recover by normal means all of the oil originally present in a sand, the actual limit being dependent upon sand and fluid characteristics. From reservoirs in which encroaching water efficiently furnishes energy to move the oil, the maximum yield may be 80 to 90 per cent of the total oil in the sand. In some fields where only gas furnishes the energy, the maximum use may be as low as 20 to 25 per cent.

There are three general means by which oil can be recovered from the sand:

1. Simple expansion of gas released from solution in the oil, no free gas cap or water source being present. This is called a "dissolved-gas drive."
2. Displacement of the oil from the sand by downward expansion of a free gas cap. This is often termed "piston-type gas-cap drive."
3. Upward displacement of the oil by influx of water from below the oil sand. This is termed "water drive."

In practice it is seldom any one means that is the sole agent in oil recovery. However, the degree to which one or the other is utilized will have an important bearing on the ultimate oil recovery.

1. *Dissolved-gas drive.* This method has the lowest efficiency of oil recovery, since it depends solely upon the relatively limited quantity of the dissolved gas for expulsion of oil from the sand. Both rate of oil flow and ultimate oil yield are dependent primarily on the degree of exhaustion of the gas. Possible ultimate yield under dissolved-gas drive will usually amount to 20 to 30 per cent of the original oil in place, thus leaving from 70 to 80 per cent of the oil in the ground only to be recovered by secondary means.

Little can be done in this type of reservoir to increase the ultimate recovery unless some outside force of energy, either water or gas, is introduced in order to supplement the natural energy. In some such fields a low rate of flow is often desirable so that it may bring about a segregation of the oil and gas released from solutions, tending to convert a dissolved-gas drive into the more efficient gas-cap drive.

2. *Gas-cap drive.* The piston-type gas-cap drive is capable of yielding substantially higher recovery than the dissolved-gas drive. By this means the displacement action of a downwardly expanded gas cap maintains pressure on the oil vent and retards the gas coming out of the solution.

The degree to which maximum recovery will be obtained under this method is in large part dependent on the ability to maintain a separate and distinct expanding gas cap during the productive life of the field. The recovery expected by this type of operation covers a wide range but will be 50 to 100 per cent greater than under dissolved-gas-drive operations. The practical requirements for effective results under this method include a higher permeable sand, gas conservation, and, usually, pronounced structural relief.

When a free gas cap does not originally exist, it is often feasible to create one by the injection of gas at the crest of the structure, or gas injection may be used to maintain and enlarge an original gas cap. Such an operation is commonly known as "pressure maintenance" and represents the most efficient form of gas-cap drive.

Withdrawal of free gas from the gas cap must be avoided in order to realize full benefits from gas-cap drive, and, similarly, careful control of the rates of production of each well must be employed to avoid channeling or by-passing of free gas.

3. *Water drive.* With this method water advances upward into the oil sand as oil and gas are withdrawn. The displacing effect of the advancing water tends to maintain pressure in the reservoir

by replacing the fluid withdrawn and to cleanse the sand of the oil. Water drive is unquestionably the most efficient natural oil-recovery mechanism in the majority of sand reservoirs since the sands are usually water-wet under original conditions and the flushing action of the water can be very thorough. In many fields in the Gulf coast, East Texas, and other areas, water drive is utilized to a high degree, and in such fields it has been found that initial yearly oil-withdrawal rates of about 3 to 5 per cent ultimate yields permit very efficient ultimate recovery.

Physical requirements for effective water drive include a large continuous and permeable reservoir, either extending as a sheet over a large area or outcropping at not too great a distance.

There have been a number of outstanding examples in recent years where water has been introduced into the reservoir below the oil-water contact to supplement the water supply if this is not sufficient to maintain the pressure. This form of pressure maintenance may materially increase not only the rate at which a reservoir can be produced but also the ultimate recovery from the field.

The amount of oil that can be obtained from a reservoir depends not only upon the nature of the reservoir but also upon the manner in which the reservoir is developed and operated. For this reason it becomes very important in a study of conservation to inquire into factors which control the recovery of oil.

There are, of course, certain factors that cannot be controlled, such as the geological and physical properties of the reservoir and of the fluids themselves.

There are many factors, however, that can be controlled and that have an important bearing on ultimate recovery. Of these, proper well spacing, well-completion methods, and the use of pressure maintenance are particularly important.

There are other factors which can be controlled during the producing life of the field, such as rate of production and the control of the production of gas and water.

A major objective of all efficient production practice is to produce oil under the most effective type of drive.

The extent to which recovery can be increased by maintaining a proper rate of production depends, of course, upon the nature of the field. Careful control of both water and gas production is a necessary conservation measure if the maximum amount of oil is to be received.

The attention of the industry was dramatically called to the necessity for conservation by President Coolidge in 1924 in a letter creating a Federal oil-conservation board. The industry began an active program of research both through individual units and through concerted action of committees appointed by the American Petroleum Institute and other trade associations. At that time there was a real shortage of oil and a feeling that the country was about to run out of oil. Shortly afterward a large number of fields were developed in Texas and Oklahoma, producing under open-flow methods far in excess of market demand. The economic pressure of excessive supplies drove the industry and the oil-producing states into a detailed consideration of ways and means of meeting the issue.

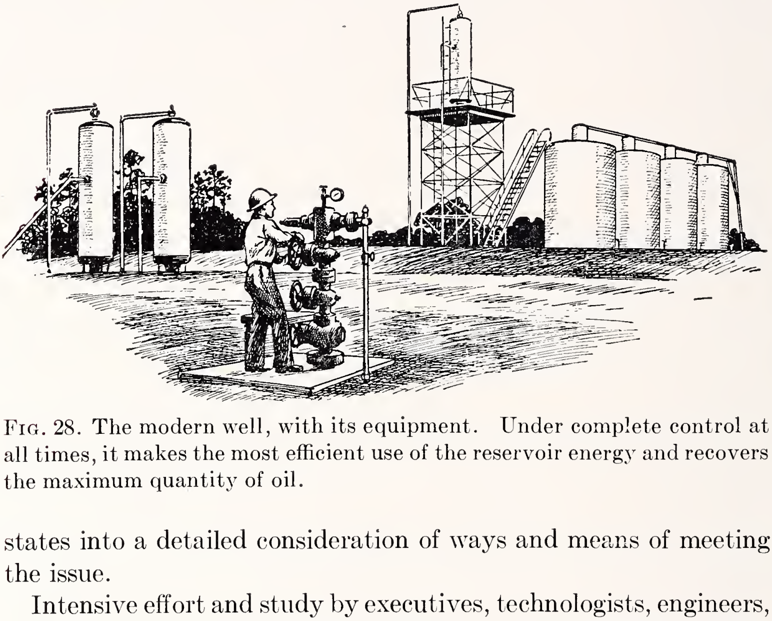

Fig. 28. The modern well, with its equipment. Under complete control at all times, it makes the most efficient use of the reservoir energy and recovers the maximum quantity of oil.

Intensive effort and study by executives, technologists, engineers, and lawyers were devoted to the problem. In view of the tendency toward waste created by the competitive race to capture oil, the excessive cost of operation under open-flow methods, and the legal difficulties involved, could a system be devised to bring about conservation?

It became increasingly clear that oil and gas are of such vital concern to the public that the public is interested in the prevention of their waste and in carrying out conservation principles and practices. It became apparent that public regulation was justified to the extent necessary to protect the public interest and to ensure the protection of the correlative rights of all operators in a field, bound together as they are by mutual, though apparently conflicting, interests, in a common reservoir.

Since the landmark case of *Ohio Oil v. Indiana* handed down by the United States Supreme Court in 1900, it had been recognized that a state is fully authorized to pass and enforce conservation legislation, both for the prevention of waste, and for the protection of correlative rights of operators and royalty owners. These ends could be attained by requiring the proper location, spacing, drilling, operation, and abandonment of wells; by regulating gas-oil ratios, controlling the rates of flow, and effecting uniform withdrawals of oil and gas throughout the reservoir; by limiting the production in the state and in the several fields to market demand; and by allocating the allowable production in a field among the wells and leases so as to enable each owner to recover his fair share of the oil.

Gradually the oil-producing states have enacted comprehensive conservation statutes prohibiting waste, creating conservation agencies, and providing the machinery for accomplishing such objectives. The process of securing such legislation has been slow, and there have been difficulty in bringing about proper administration of the statutes and a great amount of litigation testing the validity of the statutes and the rules and regulations promulgated by the conservation agency. But, in the last fifteen years there has gradually been evolved in most of the oil-producing states of the nation a system or program of waste prevention and conservation reasonably well designed to accomplish the conservation of oil.

The successful carrying out of an adequate program of conservation is a cooperative process. It involves the development and sharing of increasing technological knowledge and the combined and cooperative efforts of engineers, lawyers, regulatory authorities, and operators. It requires the enactment by the states of adequate conservation legislation, sound exercise of administrative functions by the conservation agencies, and the understanding and sympathetic interpretation of statutes, rules, and regulations by the courts. It requires cooperation between the industry and the states and a continuing process of education within the industry and the conservation agencies created by the statutes. This educational process must be continued from state to state as new producing areas are found.

The Interstate Oil Compact Commission created in 1935 is an important cog in the machinery of conservation. By legislative enactment, 20 of the major oil- and gas-producing states now have banded together for a common purpose—the prevention of waste in the production of oil and gas. By joining the Compact those states have agreed among themselves "to enact laws or if the laws have been enacted . . . to continue the same in force to accomplish within reasonable limits the prevention of:

"1. The operation of any oil well with an inefficient gas-oil ratio
"2. The drowning with water of any stratum capable of producing gas or oil, or both gas and oil in paying quantities
"3. The avoidable escape into the open air or the wasteful burning of gas from a natural-gas well
"4. The creation of unnecessary fire hazards
"5. The drilling, equipping, locating, spacing, or operating of a well or wells so as to bring about physical waste of oil or gas or loss in the ultimate recovery thereof
"6. The inefficient, excessive, or improper use of the reservoir energy in producing any well."

The Compact has grown to its present stature because it has adhered firmly to certain fundamental principles. Those basic concepts were developed in many conferences and evolved from numerous ideas. Fundamentally, those principles are as follows:

1. Some basic control over oil and gas production must be exercised to ensure their proper utilization and to prevent waste.

2. All power and authority to control production must be vested in a state agency which is on the ground, knows the problems, and has a sympathetic understanding.

3. The idea of centralized Federal control is repugnant in a free economy, but the national government can give assistance to the states in certain respects, particularly in research, and in preventing the interstate movement of oil produced in violation of state orders.

4. Interstate cooperation in the solution of mutual problems is essential for a coordinated waste-prevention program. That medium of cooperation is provided in the Interstate Oil Compact Commission.

Under the Interstate Compact to Conserve Oil and Gas, approved by the state legislatures and ratified by the Congress, it is the duty of the Interstate Oil Compact Commission "to make inquiry and ascertain from time to time such methods, practices, circumstances, and conditions as may be disclosed for bringing about conservation and the prevention of physical waste of oil and gas," and it is the responsibility of the Commission to "report its findings and recommendations to the several states for adoption or rejection."

The Compact Commission has no power or authority to issue an order or directive of any type. It does, however, have the power under the Compact "to recommend the coordination of the exercise of the police powers of the several states within their several jurisdictions to promote the maximum ultimate recovery from the petroleum reserves of said states, and to recommend measures for the maximum ultimate recovery of oil and gas."

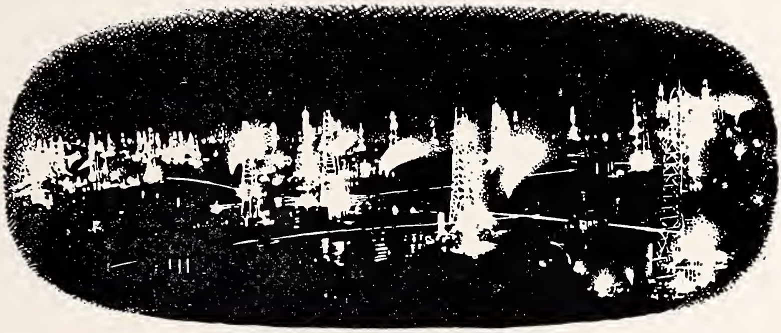

Fig. 29. Natural gas formerly was burned to get rid of it after it had escaped from the oil that it had lifted to the surface. Fields lighted at night by great gas flares are now less common.

Details of placing such recommendations in operation are left entirely to each individual producing state.

State conservation authorities and technical committees of the Interstate Oil Compact have worked with the oil industry in the development of the best methods for utilizing most efficiently all energies available in the reservoir for the recovery of the greatest amount of oil. As better and more efficient production methods were disclosed, state officilas have taken the steps necessary to ensure their adoption.

The Compact Commission's activities in promoting proper legislation, in disseminating statistical and technical information, in encouraging research, in coordinating work in the field of secondary recovery, and in bringing to the attention of the general public the great advantages of properly enforced conservation measures are well known. Under the concerted efforts of the Compact, state regulatory agencies, the Bureau of Mines, state educational and research institutions, and the technical engineers in the industry, millions of barrels of oil will be recovered for public use which fifteen years ago had been marked off as unrecoverable. Gas drives, water flooding, selective plugging, electrical surveys—all have played a part in bringing to the surface this oil which had been given up to be left with Mother Nature. Further advances are expected in the future, as all of these agencies are cooperating on a scale heretofore unknown. The Compact has been a factor instrumental in accomplishing this unity.

The Compact, of course, does not take credit for all of the scientific developments made by the industry. However, it is the author's sincere belief that the freedom from unnecessary Federal restrictions, directives, and requirements under which American industry has developed its spirit of enterprise (and which the Compact Commission has sought to protect) has been in a large measure responsible for these noteworthy advances, both in scientific practices and in conservation laws.

Through fact finding, coordination, and education, the Interstate Oil Compact Commission has blazed the path of progress in the advancement of conservation.

In the development and promulgation of more effective laws, rules, and regulations, we have enabled our lawmakers to keep pace with scientific developments.

By emphasizing the state as the proper oil- and gas-regulatory authority, the Compact has preserved to the states the fundamental rights of local self-government.

From frank, open discussion of our problems has come a better understanding, which has resulted in cooperative action for the common good.

In no country bound by governmental restriction or dominated by state control has such progress been made. In no other country have these scientific advancements been possible. It is freely acknowledged by all nations that American oil developments lead the world. The progress of state regulation and scientific advancements have gone hand in hand. We have found and produced, by any method of comparison, more oil more conservatively than has any other nation.

Through the Interstate Oil Compact Commission, twenty sovereign states have joined hands in a waste-prevention treaty—a treaty which has been largely credited with making it possible for you to drive up to a filling station and confidently say, "Fill 'er up."

Chapter V

TECHNOLOGY—THE GREAT MULTIPLIER

Part 1. EXPLORATION TECHNOLOGY

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Introduction

Oil is found in the porous permeable rocks of the earth's crust, where geological conditions are favorable for its accumulation in pools. It occurs in anticlinal and stratigraphic traps. To locate and define areas where such favorable conditions exist is the job of technicians.

During the forty or fifty years after the first commercial oil well was drilled in the United States, little technical advice was sought in the location of well sites. Oil was discovered by drilling near seepages or other surface indications and by random drilling. Since then scientific methods of search have been employed, though random drilling still yields occasional discoveries of considerable importance. Had the industry continued to explore for oil without the aid of technology, certainly our known reserves and productive capacity would now be much smaller.

Development of Technique of Oil Finding

Beginning about 1912, geologists started the mapping of outcrops to locate favorable places to drill. The results of this first application of science to oil finding were very encouraging, and within a few years most of the promising surface structures had been drilled to depths as great as possible with existing equipment and methods. Early wells were drilled by the cable-tool system with which reaching depths of 3,000 to 4,000 ft was a slow and laborious process. Rotary-drilling methods were first used in 1901 in the Spindletop field near Beaumont, Tex. With the advent of better steels this method was greatly improved, and by the early 1920's it was the commonly used method for drilling wells. Improvements in rotary-drilling equipment and materials have made available the vast oil reserves below depths of 5,000 or 6,000 ft that only a relatively few years ago could not have been reached even if their existence had been suspected. Metallurgical research conducted jointly by the steel and petroleum industries has produced such improved alloy steels that the limitations on the depth of drilling are economic rather than physical. In 1949 a well drilling in Wyoming reached a depth in excess of 20,000 ft to establish a new world's record.

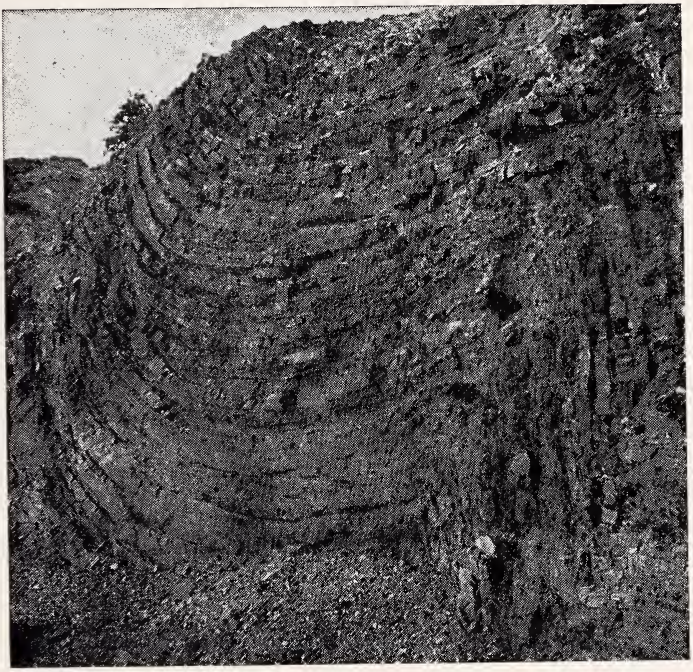

Fig. 30. Geologic folding as seen in road cut on Black Knob Ridge just southeast of Atoka, Okla.

When geologists began to appreciate in the early 1920's that many structures were invisible at the surface, the great era of subsurface exploration began. Pit digging and core drilling were used in areas where identifiable key beds were not exposed sufficiently to permit surface mapping of underground structures. More careful logging of wells and improved methods of collecting and analyzing drill cuttings vastly increased the accuracy and quantity of available information, thereby permitting the geologist to extend his knowledge of structural conditions both laterally and vertically. Paleontologists effected a correlation of geological horizons between widely separated wells through a study of microfossils, where otherwise correlations could not be made. In some regions mineralogists have been able to correlate the underground geological strata on the basis of the mineral content of the sediments. Electrical, gamma-ray, and neutron well logging all have been of great value to the geologist in correlations and in working out the details of subsurface structure. The great strides made in perfecting coring devices not only have improved production and development technique but also have vastly increased the geologist's knowledge of deeply buried formations. The many improvements along these lines, though not spectacular individually, cumulatively have furnished a wealth of assistance to the geologist and have served as the foundation of subsurface geology, which has grown from about 1920 until today it is one of the most useful methods of exploration.

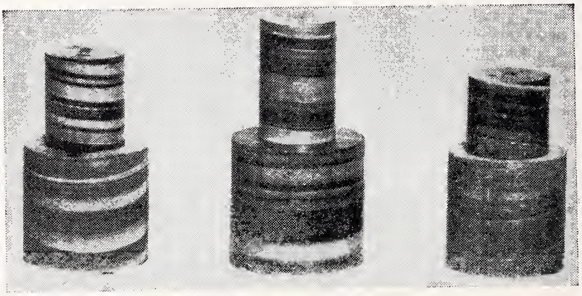

FIG. 31. Typical examples of the types of cores used for determining the orientation.

ERA OF GEOPHYSICAL METHODS

Geophysical methods of exploration were introduced into the American oil industry in the middle 1920's. One of the first of these was the refraction seismic method. German scientists attempted unsuccessfully to use this method to map geological structure in Mexico and along the Mexican fault-line zone in 1923. After several refinements they located the first salt dome on the Gulf coast in 1924, after which a number of others were found in a short time.

American technicians began experimenting with this same method in 1919, and the first field party started work in 1925. A number of improvements had been incorporated in the American technique; it was successful in locating a large number of shallow salt domes in the Gulf coast areas, many of which turned out to be productive. Refraction seismic exploration was not successful in working out small, deeply buried structures in such areas as the mid-continent. Consequently by the close of the 1920's it began to lose ground. Meanwhile American ingenuity, employing sound-ranging principles, contributed entirely new concepts to the seismic techniques, and by 1929 the reflection seismic method was developed. The vertical depth to which structures could be mapped and detailed was extended many thousands of feet. The success of the method was little short of phenomenal. In 1930 only a few crews were in the field; by 1935 the number had increased to about 50 and by the end of 1943 to approximately 250. Though the use

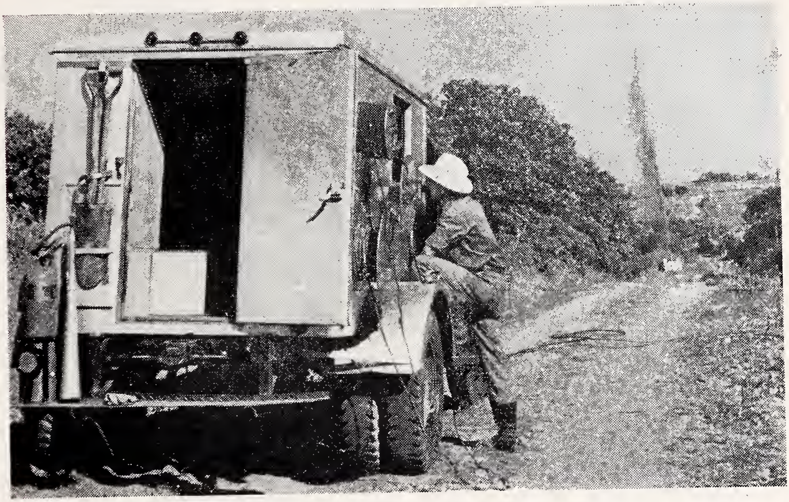

FIG. 32. Recording a seismograph shot. Recording truck is seen in foreground, shotting truck in background near shot.

of the method was curtailed rather sharply during the war owing to shortages of man power and material and also to low crude-oil prices, there was a rapid response to removal of these factors so that during 1948 nearly 500 crews were at work. Continuous refinements in the equipment permit interpretations of more and more deeply buried structures, until in many instances it is now possible to apply the method successfully to sediments deeper than it is feasible to drill. Reflection seismic exploration, as developed by American technicians, using American-made instruments and American field crews, has been used in practically every oil-producing country of the world.

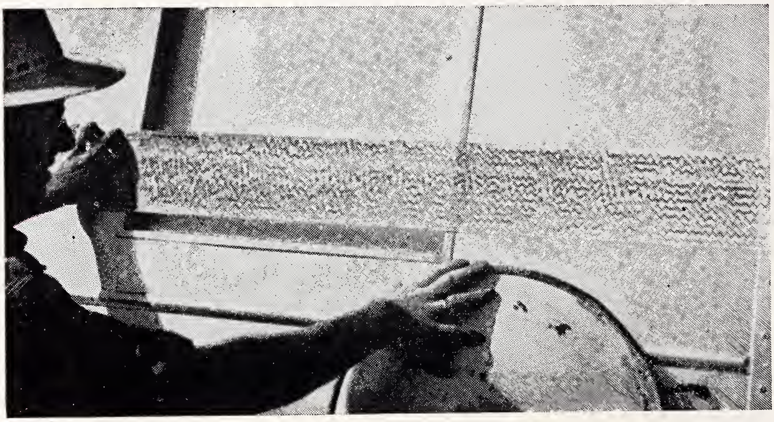

FIG. 33. A reflection seismograph record being inspected by operator after shot. Final interpretation of this record is made in the computing offices.

In 1923, at about the same time refraction seismic exploration was introduced into the United States, another oil-finding principle, the gravity method, was imported from Europe. The first instrument employed was the torsion balance, which measures local variations in the intensity of the earth's gravitational field. A Hungarian invention dating back to the 1890's, it was used with moderate success to unravel geological conditions under the great Hungarian plains. Like the refraction seismograph it proved successful in locating salt domes beneath the flat terrain of the Gulf coast but achieved little success in hilly or mountainous topography. The topographical limitations of the method and its inherent slowness with resulting high cost of operation prevented its widespread application in the search for oil.

To overcome these operational handicaps, gravity meters were designed in American laboratories with which, for all practical purposes, the same data could be obtained at a greatly increased rate and at commensurately lower cost. Moreover, the new instruments were able to operate successfully in more rugged terrain. In 1948 more than 90 gravity-meter crews were busy in the United States. Particularly successful in finding salt domes if not too

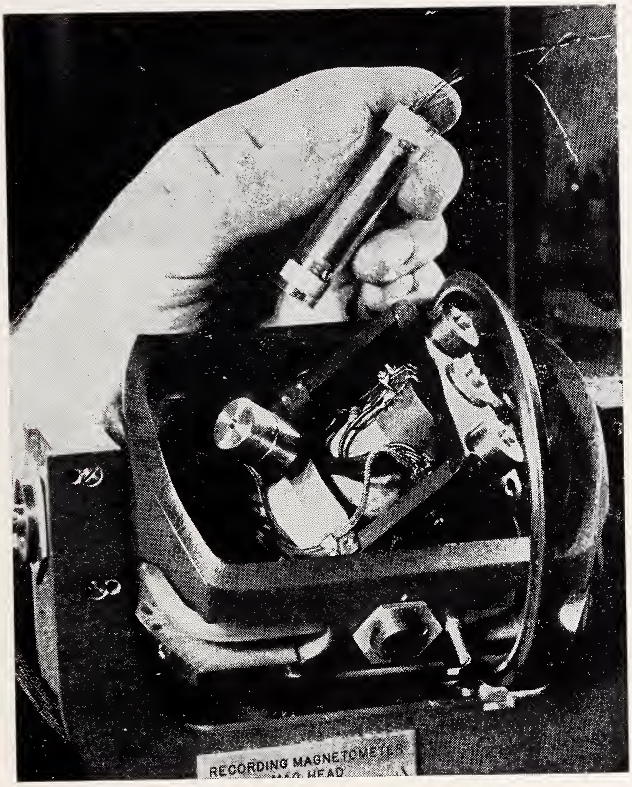

Fig. 34. The nerve center of the air-borne magnetometer, housed in a bomblike structure, is lowered beneath a moving airplane. The small tubelike piece being held in the above photograph is the heart of this instrument. It contains a supersensitive strip of metal unusually responsive to the magnetic field sent up from ferrous rock thousands of feet beneath the surface of the earth. So sensitive is this device that it measures $\frac{1}{50,000}$th part of the earth's magnetic field, transmitting this information to electronic instruments in the airplane which record it on a graph in a series of continuous measurements. *(Gulf Oil Corporation.)*

deeply buried, they have also contributed much valuable information as reconnaissance tools.

Still another geophysical method introduced in the early 1920's was the magnetic method. The most successful and widely used magnetometer is a sensitive instrument developed in Germany to measure the intensity of the earth's magnetic field. It has been a useful reconnaissance tool in mapping broad areas, and the information it yields when combined with that from other geophysical and geological methods has contributed to the record of oil finding in this country.

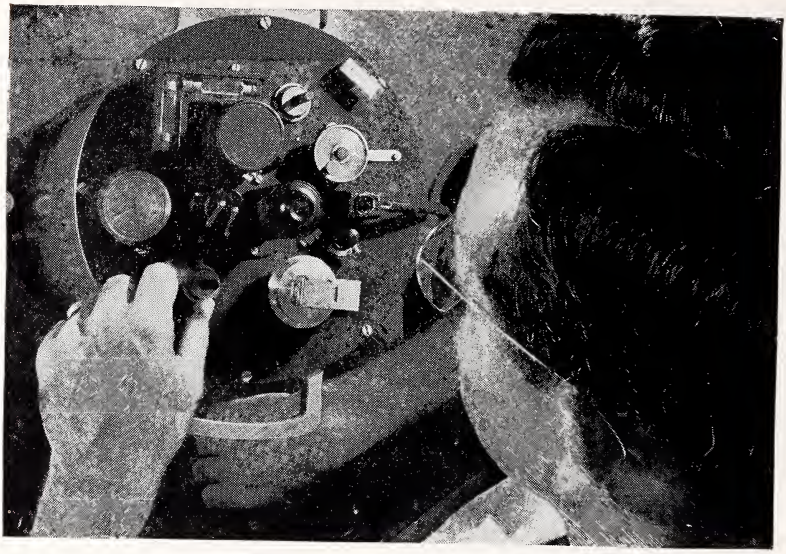

Fig. 35. Inspecting the controls of a gravitimeter.

During the war it was found that a similar type of instrument when attached to an airplane was an excellent means of detecting submarines. This so-called "flying magnetometer" has been used to carry on reconnaissance work over large areas, both accessible and inaccessible, in the never-ending search for new reserves.

Results of Exploration Technology

The discovery and steady improvement of the above-mentioned exploration methods have greatly reduced the hazard in wildcat drilling. From 1937 to 1942, 1 out of every 6 wildcat wells that were drilled on technical information discovered an oil field. However, no significant trend occurred in this figure either up or down during the period. On the other hand a wildcat that was drilled without benefit of technical advice had only 1 chance in 18 of being a producer during the same period. Moreover, the nontechnical wildcat made an increasingly poor record, dropping from 1 well out of 12 in 1938 to 1 out of 25 in 1942. Data in recent years indicate that the successful technical wildcat has dropped to 1 out of 8, while the nontechnical figures remain about the same.

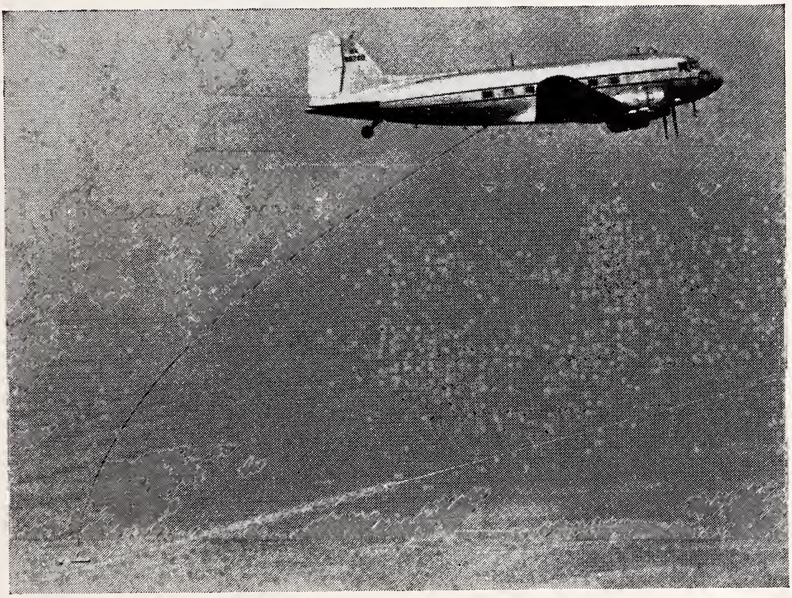

Fig. 36. This unique "bird," a flying magnetometer, is shown trailing beneath a flying laboratory to measure the magnetic strength of the earth over which it travels at about 1,500 ft altitude and 150 mph. This device permits magnetic mapping of heretofore inaccessible areas, such as jungle, oceans, and mountains. Once the magnetic strength of large areas is known, geophysicists prepare contour maps to show the formations of the rock far beneath the surface of the earth and select for further exploration the most geologically promising areas. (*Gulf Oil Corporation.*)

The effect of these changes on the national reserves is illustrated by the curve in Fig. 37, which shows the net amount of added reserves each year after taking consumption into consideration. On the average the reserves increased slowly between the points *A* and *B* on the curve up to the year 1925. If the assumption in 1925 had been that the same rate of increase would continue and that nothing unusual would happen to the discovery rate, then by projecting this curve to the point *C* it might have been anticipated that the reserves in 1942 would be between 12 and 13 billion barrels. Actually, as shown by the solid curve this figure was above 20 billion barrels. This increase in the rate of finding reserves was due to exceptionally rapid improvements in geological methods and to the adoption of geophysics, which as previously noted occurred between 1925 and 1930. Random drilling undoubtedly accounted for part of the increase, but for reasons mentioned elsewhere in the report no effort has been made to segregate the discoveries of the various methods. The actual accomplishment was even greater than shown. The annual consumption increased from about ½ billion barrels in 1925 to nearly 1½ billion barrels in 1942, so that a minimum of 5 billion barrels more oil was consumed in this period than might have been expected, even allowing for a steady increase at the 1915 to 1925 rate. With the exception of a short period near the end of the war, reserves have risen slowly each year in spite of increasing production, which in 1948 attained a figure in excess of 2 billion barrels. It would not be unreasonable to expect that the combination of further improvements in exploration plus the introduction of a new method might

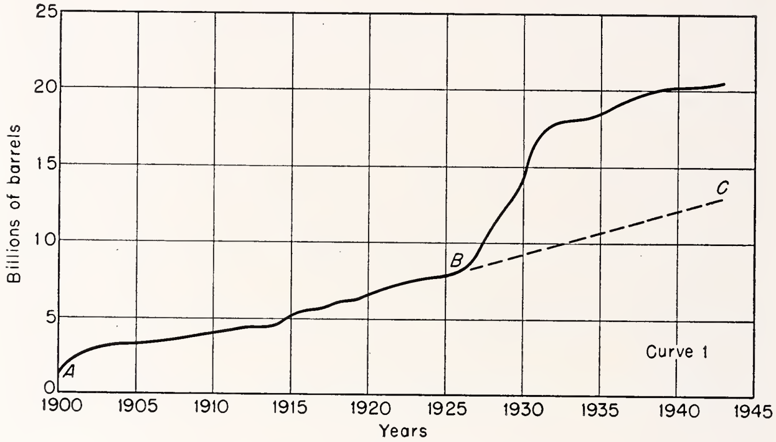

Fig. 37. Approximate reserves.

add very substantially to our net reserves over the next twenty years.

Search for New Exploration Methods

The problem of finding oil in stratigraphic traps is one of the most important problems facing the oil industry today. It will have to be solved by the intelligent combined use of all available tools and by new methods and improvements in old methods. The industry spends several million dollars a year in research designed to develop new techniques and improve old ones. Investi-

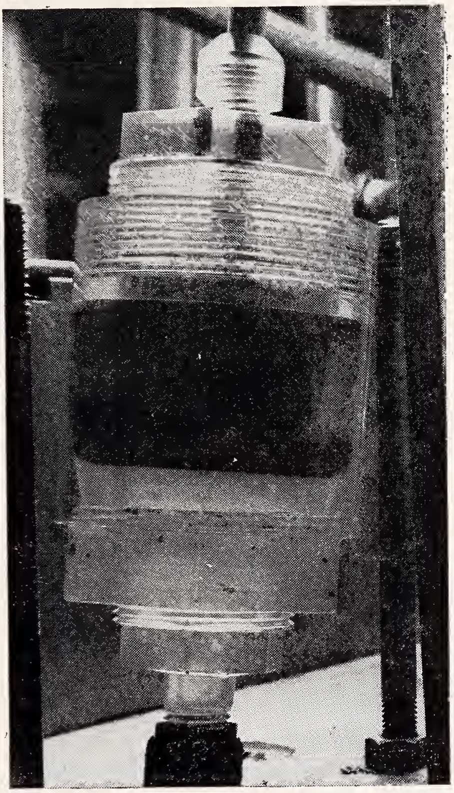

Fig. 38. A cell used to test characteristics of a core. In this cell, underground conditions similar to those found in nature can be duplicated. (Core is saturated with oil; water is let into bottom of cell, displacing the oil; time and amount of displacement is then used in studies of underground characteristics.)

gations, although somewhat slowed down because many scientists were engaged in war work, are currently being conducted on such problems as:

1. Direct oil finding by electrical or geochemical methods
2. Mapping geological anomalies with radio waves
3. Further refinements of seismic techniques
4. Adaptation of various physical instruments such as the electron microscope, the mass spectrograph, and the X ray to the detailed study of well samples and cores
5. The origin of oil and the transformation of organic material into hydrocarbons
6. Broad studies of basic geological processes and intensive study of subsurface data accumulated from old wells and from more recent stratigraphic tests

Enormous advances in radio technique and equipment and in the development of new implements and weapons of war have given rise to hope that new methods will be developed that can be applied to oil finding. Radar and associated electronics constitute a vast field which might revolutionize the oil-finding methods of the future even though tremendous obstacles remain to be overcome, such as the earth's very high absorption of short radio waves

FUTURE PROSPECTING

Prospecting, which involves many highly complicated techniques, is carried on in three dimensions. Laterally, it helps localize new areas displaying characteristics favorable to the accumulation of petroleum; vertically, it involves search for new oil by deeper drilling on known and in many cases already productive structures. In one sense the latter is less hazardous than the former; more definite knowledge about the structure is available from wells already drilled. There are enormous volumes of untested sediments on structure and below the presently drilled depths that in all probability will yield huge quantities of oil. Fortunately, metallurgical improvements that made it possible in the past twenty years to double the maximum drilled depth have advanced to a point where this deeper drilling offers no serious technical difficulties.

The urgency for development of increased productive capacity during the war had a tendency to confine lateral exploration to the less hazardous but already carefully examined areas in proximity to production. This fact undoubtedly accounted in part at least for the continuing decrease in the size of new discoveries. Since the war, exploration has been less concentrated, and activity has spread to large areas where existing techniques have never been applied but where there is good geological reason to expect favorable conditions for oil accumulation. Much Federal land in some of these areas has recently been leased. Exploration has been encouraged by modifications in the Federal land-leasing regulations.

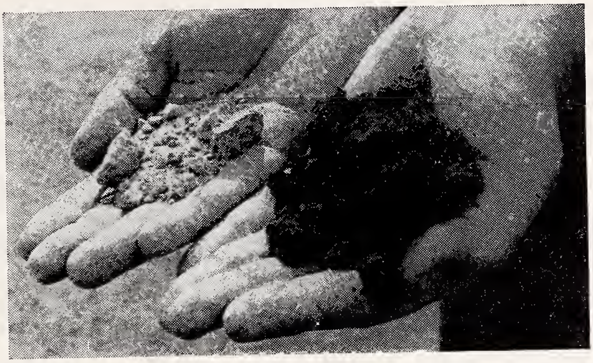

FIG. 39. Sample of oil-saturated Simpson sand (dark) from asphalt pits contrasted with sample of dry sand (light).

Highly specialized seismic techniques and equipment have been developed to cope with the problems of exploration in the open waters of the Continental Shelf. It is now possible to examine such an area with much greater rapidity than on land. Radar is being used for surveying in much of this work. Gravity data are being obtained by placing the instrument and observer in a diving bell or by recording the gravity readings electrically.

Substantial reserves of oil have been found off the coast of Louisiana on the flanks of recently discovered salt domes, and the intensity of exploration and leasing indicates that large additional reserves may be expected. Fortunately the depth of the Gulf of Mexico increases quite gradually, so that it is necessary to go from 10 to 40 miles offshore before a depth of 10 fathoms is reached. That area off the coast where the Gulf is less than 10 fathoms deep must contain a large number of such structures, for an equivalent area on land encloses 30 domes in Texas and 50 in

Louisiana. Other portions of the Continental Shelf should further augment reserves.

Two factors are exercising a retarding influence on the development of these reserves. One is the legal question of ownership, which is a highly controversial issue between the states of Texas and Louisiana on the one hand and the Federal government on the other. The other is the very high cost of drilling and producing in deep and open water. Great engineering progress has been made, but such operations are much more hazardous and costly than on land.

Whenever a new and successful exploration method has been developed, the tendency has been to use it for a few years almost to the exclusion of all others. Then it takes its place along with older methods, to be used either by itself or in combination with other methods for the best solution of the particular problems involved in the exploration of a given area. In the course of the use of any new method large numbers of anomalies are found, the significance of which cannot be fully appreciated because they do not conform to the anticipated pattern. Generally it is decided to let such anomalies await a new instrument or a method of higher resolving power. Occasionally they are drilled before the advent of a new method, and a large oil field is discovered. Toward the end of the refraction era many such anomalies were found. They were immediately subjected to severe scrutiny when the reflection method was introduced, and a number of important new oil fields were discovered. At the present time many more anomalies are known of than at the end of the refraction period because of the relatively greater amount of reflection work. Many will undoubtedly turn out to be associated with oil fields. These areas would serve as the immediate happy hunting grounds of a new method, and the discovery rate of the new method would be abnormally augmented until such areas were exhausted. In the absence of a new method these anomalies will be reworked with gradually improving techniques, until in some cases it will be possible to work out a satisfactory structural picture. Such improvements in technique may also make it possible to map some hitherto unworkable areas. It will be necessary to drill substantial numbers of exploratory or wildcat wells in order to evaluate such anomalous areas and to obtain valuable geological information concerning subsurface conditions. Finally, random drilling can be expected to contribute substantially to our new reserves, just as it has in the past.

A critical examination of all existing geophysical data, together with information obtained from improved electrical and possibly even new logging methods, will augment the geological knowledge of subsurface conditions and thereby assist in the discovery of both stratigraphic and structural traps.

Fig. 40. Laboratory technician engaged in experimental work in connection with soil analysis.

Possibly further developments in geochemistry or soil analysis may be applied successfully to oil finding. Results to date along this line of investigation have not been impressive, but field tests of the method have not been extensive enough to prove that it is of no value.

One of the outstanding characteristics of exploration technology is its dynamic nature. New methods are promptly adopted and given extensive and widespread trial. A common practice is to use several different methods in a given area, check the results of one against another, and weigh the probability of oil-field indications before a well is drilled. As a result of the rapid succession of new methods that have been developed and the interrelation of different methods, it can hardly be said that any exploration method used to date has exhausted its capabilities as an oil-finding tool. This tendency to use several independent exploration methods in the same area has greatly reduced the risk and the expense of finding new oil fields but has made it impractical to allocate the credit for discovery of definite amounts of new oil reserves to a specific method or methods. For example, a careful study and interpretation of all available geological information,

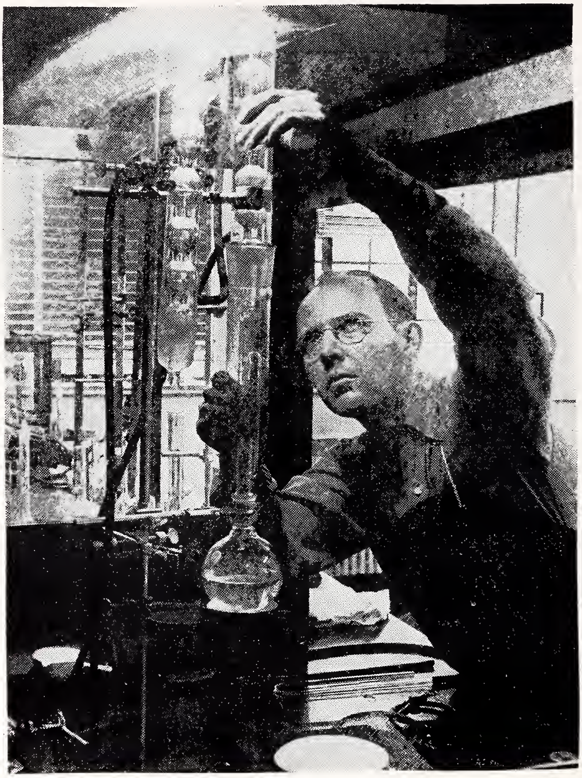

Fig. 41. Chemist in geophysical and production research laboratory.

including surface work, may indicate the possibility of a regional trend. A gravity survey shows that the area is somewhat anomalous but fails to reveal any structural details. A core-drilling program indicates rather weak structure, so that a seismic survey is finally made. This process not only indicates the trend but also isolates the area on which to drill. If the test well is productive, it would be very difficult to determine which of the methods should be given credit for the discovery.

Conclusion

Vast untested areas on land and under shallow water still remain to be explored. Deeper drilling of presently known structures should add substantially to our reserves. Random drilling has made effective contributions to our oil reserves in the past, and unquestionably it will do so in the future.

While no new methods are in sight at the present, there is ample reason to expect that new techniques will be developed which will also uncover additional reserves. Meanwhile the American petroleum industry will continue to use all available instruments and methods in the search for oil. Even tools of doubtful value will be tested. The best approach to the problem of search for stratigraphic traps is through the greater use of slim holes for purely exploratory drilling. The oil industry is fully prepared to extend the use of this tool if no better approach presents itself.

Most of the advances in exploration technology made by any single American company shortly becomes available to all companies. By employing service companies the smallest oil producer may benefit from the techniques available to the largest company. This immediate availability is primarily an American development, and unquestionably it has played an important role in maintaining American methods and techniques in the preeminent position they hold in oil exploration in all parts of the world.

The petroleum industry of the United States, developed under a system of competitive endeavor and free enterprise, can be justly proud of its record in oil exploration and development. Given a chance to exercise its ingenuity and courage, the industry may be relied on in the future to provide the necessary oil products from oil or substitutes to keep the wheels of industry and transportation moving.

Part 2. PRODUCTION TECHNOLOGY

By John M. Lovejoy

President, Seaboard Oil Company of Delaware

At an early date oil operators learned that petroleum deposits were different in character from solid minerals. Whereas the latter remain in place until the owner elects to recover them and regardless of production from other portions of the same deposit, oil is fugacious and will migrate to areas of lower pressure. Thus the first wells in a new field, creating areas of low pressure, frequently drained oil from under neighboring properties. The long-established law of oil and gas known as the "rule of capture" gives the owner of oil-field land all the oil which he can reduce to his possession, whether or not all such oil originally underlay his particular trace. Upon discovery of a new field, therefore, it behooved every operator to develop his property as rapidly as possible and produce it at maximum capacity so that he might obtain the maximum share of the total oil recoverable from the field. Under such practices operators observed that the first wells obtained the highest recoveries, that unrestricted producing rates yielded higher recoveries, and that more densely drilled tracts obtained more oil per acre than adjoining tracts with wider well spacing. These observations led to the conclusions apparently that rapid development, close well spacing, and maximum producing rates resulted in maximum recovery. Now it is known that these conclusions were unsound and that practices in vogue in the early years of the industry incurred gross economic waste and were detrimental to the maximum recovery of oil from the field as a whole.

The first technological investigations of petroleum production were undertaken by the U.S. Bureau of Mines. Shortly after the First World War petroleum engineers were introduced into the industry, and producing companies began the establishment of research laboratories. These technologists supplemented and greatly expanded the early studies of the Bureau of Mines. As a result of these studies some of the factors which influence the efficiency of oil recovery were recognized, and the first principles of reservoir behavior were formulated. However, not until a series of great new discoveries in the middle twenties culminated in vast overproduction of oil was it necessary to curtail producing rates to avoid surface waste. Engineers were given their first opportunity to apply the theories of scientific operating methods that were designed to increase the ultimate recovery of our oil reserves. The beneficial results of scientific control soon were demonstrated. Since that time rapid strides have been made in petroleum-production technology; we have learned more regarding the science of efficient production since the First World War than in all the time since the Drake well was drilled in 1859.

Evolution of Conservation Laws

Maximum recovery of oil from an underground reservoir requires that the individual wells and the field as a whole be so operated as to control and utilize effectively the natural energy associated with the oil. This goal can be achieved only when all the owners of production in the field employ efficient producing practices. One operator, by employing wasteful practices, can prevent or completely sabotage the efforts of his neighbors to increase the total oil to be recovered from the field.

His argument that it is more desirable to produce his oil more rapidly, even if he can recover only one-half or one-third the amount otherwise obtainable, might be sound from his particular economic point of view, but certainly it is not in the best public interest. The application of scientific producing practices required a means of enforcing the necessary regulations and control measures.

Under the rule of capture each operator was free to develop and produce his properties as he saw fit. With the restriction of production to market demand in order to prevent surface waste, the initiative of the individual operator was curbed. Therefore it was necessary to protect his property rights and devise a system of control that would give to each operator the same portion of the total recovery of the field as he would have obtained without restrictions. Thus was proration born.

Early state laws concerning oil and gas consisted merely in regulation of such features as well completions, protection of fresh-water sands, and plugging of abandoned wells. With the advent of production restriction the laws of most states were expanded to include control of proration. They were first designed merely to distribute the market demand equitably to the several operators in each field so as to prevent surface waste. With the development of technological knowledge it was soon recognized that restriction of production accomplished a far more important result, namely, more efficient utilization of the reservoir energy to achieve a substantial increase in the ultimate recovery. The proration laws were expanded to include subsurface waste and thereby became conservation laws in the full sense of the term.

The state laws of oil conservation with a few glaring exceptions are adequate to safeguard properly the interests of the nation in preventing wasteful practices and at the same time the interests of the individual producer so that each has an equal opportunity to recover his equitable share of the oil contained in the reservoir. The conservation laws have also been effective in furthering the applications of scientific principles to oil production as technical knowledge has expanded.

Review of Technological Advances

Technology is the great multiplier of our petroleum resources. Entirely aside from improvements in exploration technology which have contributed substantially toward increased discoveries of petroleum, the advances in the technology of drilling, completing, and producing oil wells and the technology of reservoir operation have made available today many billions of barrels of oil which it would not have been possible to recover through practices in vogue at the close of the First World War. Technological advances in drilling and producing operations over the past quarter century may be subdivided into two general categories, the first embracing those which are of a mechanical nature and the second relating to more efficient reservoir operation. These advances have not been brought about by any particular group in the petroleum industry but are the result of an industry-wide effort to improve operating efficiency and reduce operating costs. The advantages stemming from these advances are available to the entire industry. The technological advances are reviewed briefly in the following discussion.

Mechanical Developments

Drilling. Twenty-five years ago the deepest well drilled was around 7,000 ft, and 5,000-ft wells were uncommon. Today a well 5,000 ft in depth is considered relatively shallow, and many fields are producing from below 12,000 ft, or 2 miles below the earth's surface. In 1949 a well drilling in Wyoming reached a depth of over 20,000 ft—a new world's record.

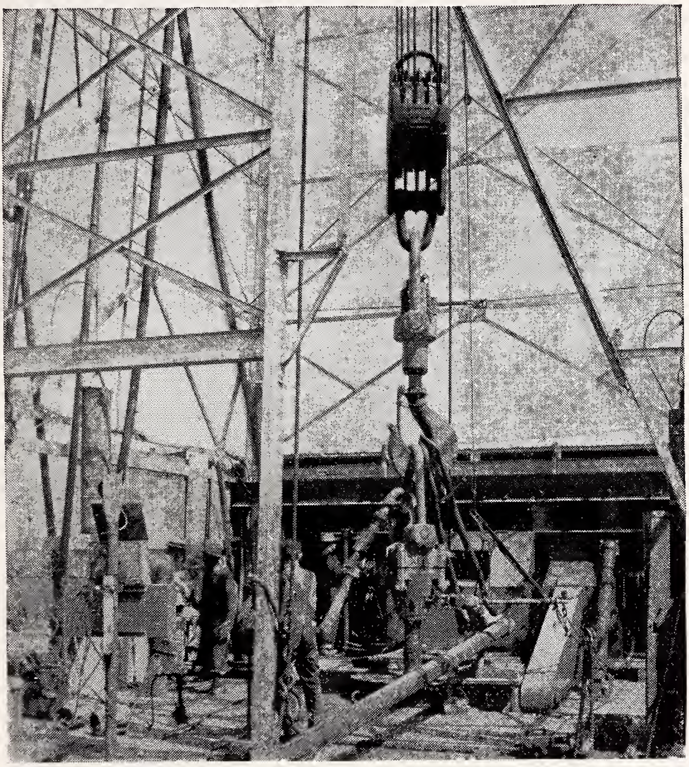

FIG. 42. Reading from top to bottom in a rotary oil-well drilling assembly: The "traveling block," a giant pulley supported by cables which raises and lowers the drill bit and pipe; the "hook," on which is hung the drilling tools; the gooseneck pipe, through which drilling mud is forced through the drill pipe into the hole; the "swivel," which permits the pipe to revolve; the "kelly" square, or grooved rod, attached to the drill pipe; the "rotary table," the circular, geared table through which the kelly and drill pipe extend. Rotation of the table turns the drill pipe and drill bit, causes grinding and boring action.

The drilling of continually deeper wells has been possible through:

1. General improvements in the design, strength, and power of drilling machinery.

2. Metallurgical progress in the manufacture of alloy steels and advance in fabrication of drill pipe, casing, tubing, and pumping equipment.

3. Scientific control of drilling fluids resulting in greater drilling speeds, minimum formation carving, drilling through the formations previously impossible to penetrate with ordinary drilling muds, and security from blowouts.

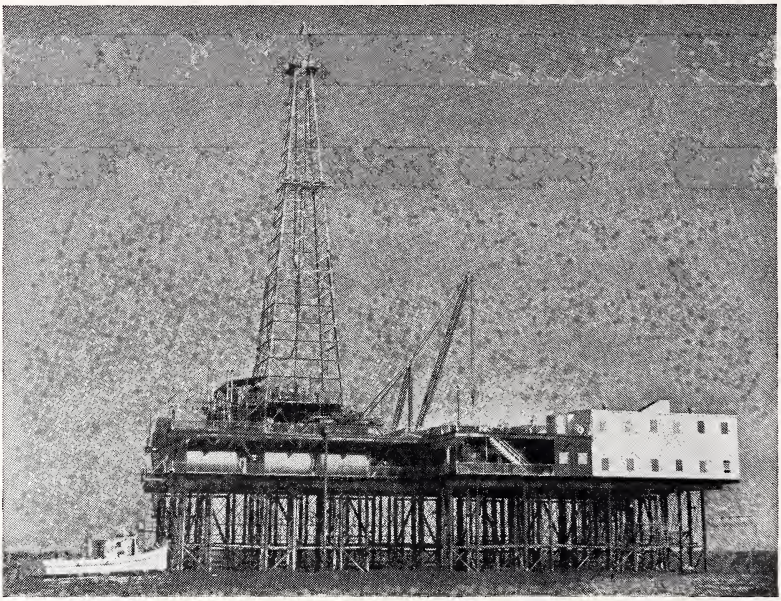

Fig. 43. Off-shore drilling operations off Grand Isle, La.

4. Improvements in cements and cementing practices, and development of techniques satisfactory under high subsurface pressures and temperatures.

5. Development of subsurface well-surveying instruments and directional-drilling techniques. Also, the application of directional drilling has made reserves available under the deep coastal areas by drilling from shore locations.

6. Development of suitable equipment for drilling from barges and special foundations in lakes, bays, and shallow-water areas of the Gulf coast. These techniques have added thousands of square miles of prospective oil area and have added substantially to crude-oil reserves.

Subsurface Information. In the earlier drilling operations, information on subsurface strata was secured only from earth cuttings brought to the derrick floor in bailers or in the drilling-mud stream. These cuttings were used to evaluate the various formations penetrated by the drill and to locate their relative vertical position in the well. As the need for better information became apparent, coring devices and other methods of evaluating the formations penetrated were invented.

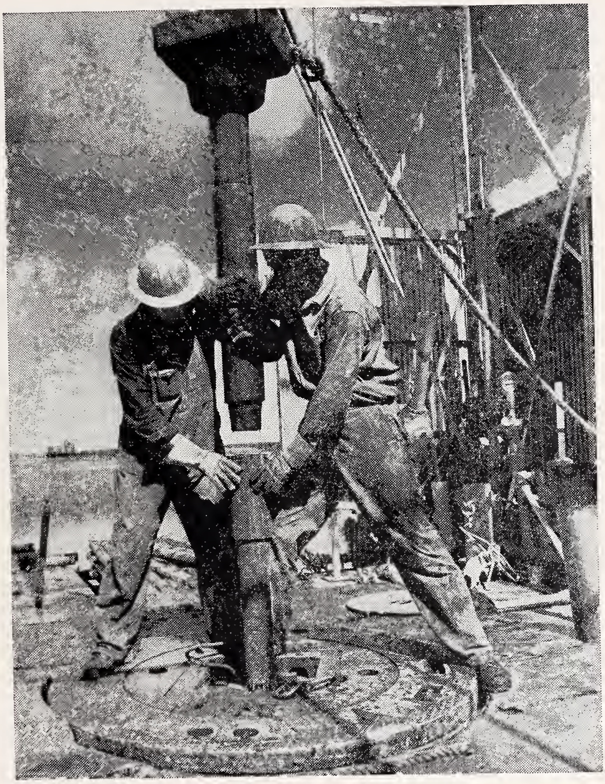

FIG. 44. Connecting drill pipe.

Progress in this direction is indicated by the following developments:

1. Inventions and improvements in side-wall, pressure, and wire-lined core barrels, which obtain samples of formations penetrated by the drill stem, have improved earth-testing technique and oil prospecting.

2. Introduction of electrical well-logging equipment has greatly assisted in the correlation and evaluation of subsurface strata and consequently has improved completion practices. The early techniques were applicable only before casing was set, but recent developments make logging possible through the casing and thus provide a means of evaluating formations behind the pipe in old wells.

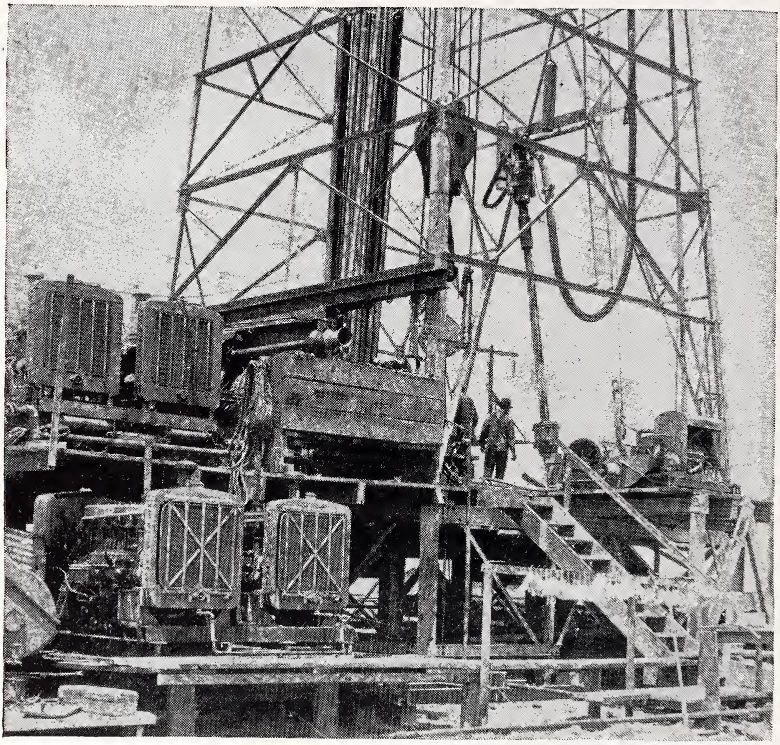

Fig. 45. Four diesel engines provide the power to operate the rotary drill in this oil well, as well as the "draw works" for letting the drill pipe into and withdrawing it from the hole and the mud pumps, which force drilling mud to circulate in the hole. The hollow drill pipe, seen standing inside the derrick, puts the bit 15,000 ft or more into the earth in the search for oil.

3. Formation drill-stem tools and techniques make it possible to test subsurface strata without setting casing. Prospective horizons can now be tested to determine whether they are water-

or oil-bearing with only a few hours' interruption of drilling. This practice assists in thorough evaluation of the penetrated formations.

4. Core-analysis equipment and techniques have been perfected so that core samples of formations can now be tested immediately upon their recovery at the surface and possible reserves recognized in the process of drilling. Complete truck-mounted laboratories provide this service at the well to any wildcatter in order to make available information as to porosity, permeability, and fluid content of the core samples of the strata.

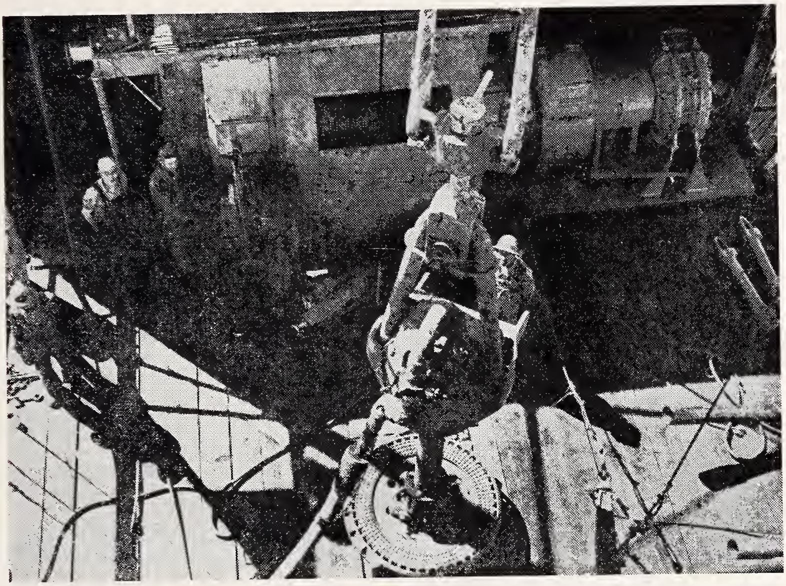

Fig. 46. Looking down from the "first girt" of an oil derrick to the rotary table. The kelly is approaching the end of the run, bringing swivel down close to the rotary table as the well deepens. Next operation will be to attach an additional joint of drill pipe, the end of which may be seen to right. Note size of draw works in background and use of hard hats by drilling crew.

5. Examination of the drilling fluid under ultraviolet light and other special tests assist in determining the fluid content of formations penetrated by the bit.

Completion of Oil Wells. With the advances in deep drilling, better equipment and new methods have been developed that made possible exploitation of reserves from productive strata otherwise uncommercial or difficult to reduce to possession. Some of these developments are as follows:

1. Selective well completions by gun perforation of steel casing. Guns are lowered on cables, and bullets are fired at points opposite the prospective oil strata. Thin oil-bearing strata otherwise noncommercial are being exploited now by this method. Similarly cased-off oil zones discovered by new well-logging techniques are opened to production by gun perforation.

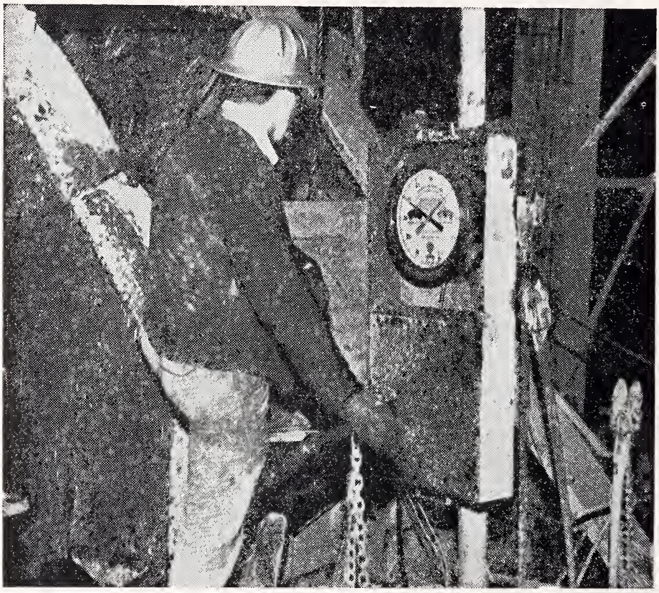

FIG. 47. Drilling gauge shows speed of the drill bit, pressure on the bit, mud pressure, and other information from which the driller controls his drilling machinery. High-speed, deep-well drilling as practiced in the petroleum industry today is a job for highly skilled men, aided by scientific, precision instruments.

2. High-pressure deep wells require slow and controlled methods of completion and production and special high-pressure wellhead equipment. Casingheads with special features and capable of withstanding pressures up to 10,000 psi were developed and are available for handling of high-pressure oil and distillate fields. Development and use of special surface and subsurface chokes

have prevented waste of reservoir energy and thus increased recoverable oil reserves.

3. Introduction of squeeze- and stage-cementing techniques assisted greatly in completion of deep wells. Squeeze cementing is also used extensively to shut off salt water for protecting oil-bearing zones from harmful underground-water pollution.

Fig. 48. Reading the "electric log" of a deep well. (*Petroleum.*)

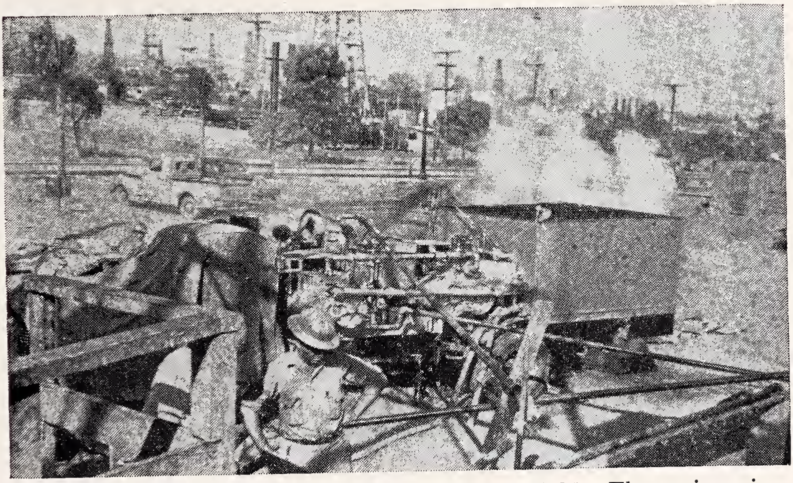

Fig. 49. Cementing an oil well in a California field. The casing pipe, through which the oil flows from the producing zone, is cemented firmly into place. The cement prevents water intrusion through the sides of the well and stops caving. For security the bottom of the casing string rests on a plug of cement.

4. Selective water shutoff by plastics is a recent development of great possibilities, the application of which is expected to improve exploitation efficiency of oil reservoirs operated by water-drive energy.

5. Introduction of acid treating of limestone-producing strata has added substantial reserves of crude oil. Acid treating of oil wells not only increased recoverable reserves from semicommercial pools but in many instances made noncommercial pools attractive for development and exploitation.

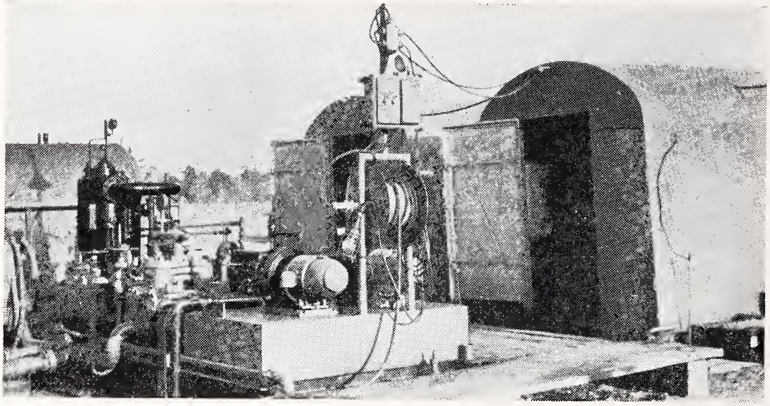

Fig. 50. Mud pumps circulate fluid mud to the well bottom and back to the surface. The flowing mud flushes cuttings from the well, tends to cement the well sides to prevent cave-ins. In the background are two "dog houses," used as storehouses and locker rooms for the workers, and a boiler in which steam is generated for the operation of the rotary drill rig.

Production Practice. Parallel to advances in drilling and well-completion methods, new developments have taken place in production practices to take care of new problems in production of crude oil from deeper wells. Here it was necessary to devise economical means of lifting fluids from great depths and to improve equipment capable of handling great loads under severe conditions of corrosive salt water and gas. The most noticeable advances in this direction are indicated by the developments listed below:

1. Development of high-capacity electric and hydraulic pumping equipment capable of lifting up to 3,000 bbl daily from shallow wells; or from deep wells in conjunction with gas-lift methods.

2. Application of electric and hydraulic pumps for deep-well pumping.

3. Improvements in pumping units and sucker rods that extended sucker-rod pumping to deep wells.

4. Improvements in gas-lift practice.

5. Successful use of screens, gravel packing, improvements in subsurface pumps, and other numerous innovations have added greatly, when viewed collectively, to the art of oil production and reservoir exploitation.

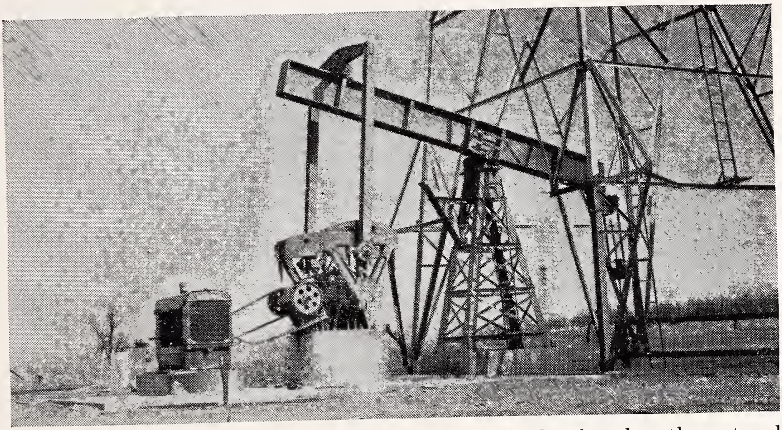

Fig. 51. Powerful pumping units lift oil from great depths when the natural pressure of an oil well is exhausted. Illustrated is a pumping unit, powered by a gas-burning engine. Each pump is carefully regulated and adjusted as to speed and length of stroke to obtain the greatest production from the well to which it is attached. Wells which cease flowing under natural pressure are kept producing for years by scientific pumping methods.

Advances in Efficiency of Reservoir Operation

The advances in understanding of the principles of reservoir behavior and the factors affecting recovery have contributed more to our present reserves of petroleum than any other single development. At the end of the First World War it was common practice to develop fields with dense well spacing and produce the wells as rapidly as possible. While it was recognized that only a small portion of the recoverable oil was being obtained by these methods, it was the common belief that this was merely the nature of oil reservoirs and that there was nothing the operator could do to improve the recovery efficiency. It is now generally accepted by petroleum-production technologists that control of producing rates and conservation of reservoir energy have a very important influence on the recovery efficiency and that the practices of early years not only resulted in gross economic waste but also caused large losses in ultimate recovery of oil.

A brief review of present concepts of the principles of reservoir behavior follows. Just as practices in vogue twenty-five years ago are now considered inefficient in the light of present knowledge, so also will continuing study add to our knowledge and further improve our efficiency of oil recovery.

Reservoir Fluids. Fundamentally, natural oil reservoirs consist of porous and permeable rock, the pores of which contain oil and gas. In all reservoirs the contained fluids are under pressure, and the characteristics of the oil and gas in the reservoir are greatly different from those at the surface. Reservoir oil is usually saturated with gas at the original reservoir pressure, and any gas in excess of that which can be dissolved at the prevailing temperature and pressure exists as a free gas cap in the highest portion of the reservoir.

The gas dissolved in reservoir oil plays an important part in the oil-recovery mechanism, both in its effect on the oil characteristics and in actual expulsion of oil from the reservoir rock. The dissolved gas increases the API gravity of the oil and reduces the viscosity and surface tension. The reduction in viscosity facilitates the flow of oil to the well bore, and the reduction in surface tension results in less adhesion of oil to the sand grains, leaning toward a higher recovery of the reservoir oil. It is therefore important to maintain reservoir pressure so as to retain the gas in solution if these beneficial effects are to be realized.

The knowledge of the fluid content of oil reservoirs has progressed through several stages. At one time the idea was prevalent that oil as recovered at the surface occupied the entire pore volume of the reservoir rock, but it was later realized that the oil in the reservoir contained gas and that the release of gas from solution caused a shrinkage of the original reservoir oil volume. It has also been found in recent years that oil and gas do not comprise the entire fluid content of even oil-saturated reservoir rocks, water usually being present in substantial amount. The initial interstitial water, commonly called "connate water," is now believed to occupy the smaller pores of the sand owing to the action of capillary forces. The connate-water saturation encountered in practice varies considerably with the character of the sand and the fluids but generally ranges from 10 to 40 per cent and in some cases may be considerably higher. The connate water in most instances is not produced with the oil and is therefore not apparent except where cores are carefully obtained and analyzed. Early estimates indicated recoveries from oil reservoirs to be in the neighborhood of 15 to 25 per cent. In view of our present knowledge of the shrinkage of reservoir oil upon liberation of dissolved gas and the presence of connate water in the oil sand, it is now realized that the percentage of oil recovered from the reservoir rock is in most cases substantially higher.

The oil-bearing portion of a formation usually constitutes only a small portion of the total stratum. The portion of the stratum extending downdip and away from the productive portion is usually porous and is commonly filled with water. In thick sections, free water may also underlie the oil zone. This water moves into the oil zone as fluids are withdrawn therefrom, and this phenomenon contributes greatly to the recovery of oil.

As may be seen from the foregoing, many oil reservoirs contain three fluids, free gas, oil and dissolved gas, and free water. As a result of gravitational segregation over geologic time, free gas, if present, will be found occupying the highest portion of the sand and will be underlain by the oil zone, which in turn is underlain by water. While this layer arrangement holds as a broad picture, there is seldom a sharp line of demarcation between oil and gas and between oil and water because of capillary forces that cause a region of gradual change in saturation from one of the fluids to the other. This is particularly true with respect to the oil-water interface.

Flow of Fluids in Sand. The flow of reservoir fluids through porous media is a mechanism in which pressure, relative permeability to oil, gas, or water, and relative saturation of the three fluids are gradually changing. When simultaneous flow of more than one fluid is involved, as happens when gas or water is flowing with the oil, a complicated system is set up in which oil flow no longer follows the simple mechanism governing its flow when alone. Permeability to each fluid after flow is established is dependent upon the relative saturation of the pore space. As a result of research investigations it has been found that the saturation-permeability phenomenon and the influence of capillary action fix a certain minimum oil saturation in a sand below which it is not possible to have flow or to recover oil by displacement. The oil remaining in the sand when displacement is no longer possible is termed the "residual-oil saturation," and the amount of oil which can be recovered before this point is reached is termed the "recoverable oil." The residual-oil saturation varies with the characteristics of the oil and of the sand, but for conditions normally encountered the minimum oil saturation practically obtainable in the flooded portion of the sand usually ranges from 10 to 20 per cent of the pore space. Thus, after taking into account the connate-water content of the sand, the maximum recoverable oil represents 60 to 80 per cent of the original oil in place, depending upon sand and fluid characteristics.

Recovery Mechanisms. Since oil in itself has no inherent energy, it can be appreciated that recovery of oil from reservoir rocks is a process involving the displacement of the oil by either gas or water. It is now generally recognized that nature has provided three major mechanisms by which oil may be recovered from underground reservoirs:

1. Through simple expansion of gas released from solution in the oil, no free gas cap or water source being present
2. Through displacement of the oil from the sand by downward expansion of a free gas cap
3. Through upward displacement of the oil by the influx of water from below the oil sand

These processes, generally referred to, respectively, as dissolved-gas drive, gas-cap drive, and water drive, are discussed briefly below:

1. The dissolved-gas drive is the least desirable type of reservoir since the recovery of oil depends solely on the relatively limited quantity of dissolved gas available for expulsion of oil from the sand. Both the rate of oil flow and ultimate yield are dependent primarily on the degree of exhaustion of the gas. The ultimate yield from this type of reservoir amounts to only 20 to 40 per cent of the original oil in place. However, by proper operating practices it may be possible to bring into play one of the more efficient recovery mechanisms.

2. The gas-cap drive is capable of yielding a substantially higher recovery than dissolved-gas drive. The displacement action of a downwardly expanding gas cap maintains pressure on the oil sand and retards evolution of gas from solution. The recovery expectancy may be as much as twice that obtained under dissolved-gas drive, with a potential yield under favorable conditions approaching the limit of minimum residual-oil saturation, thus obtaining substantially 100 per cent of the recoverable oil. Where an original gas cap does not exist, it is often feasible to create one by injection of gas at the crest of the structure; this practice may also be followed to supplement an original gas cap.

3. The water-drive mechanism is inherently the most effective natural means of displacing the oil and its dissolved gas. The advancing water flushes the oil from the sand and tends to maintain pressure in the reservoir by offsetting the fluid withdrawals. Under favorable conditions the oil content of the sand is reduced to the minimum residual-oil saturation, thus obtaining 100 per cent of the recoverable oil. The efficiency of this mechanism is apparent, since the sands are usually water-wet under original conditions and the flushing action of water can be very thorough. The physical requirements for effective water drive include a large, continuous, and permeable water leg extending regionally as a blanket sand over a large area or outcropping at not too great a distance. The presence of major sedimentary changes and regional faulting, if they destroy the effective continuity of the water leg, will generally preclude the effectiveness of the water drive as a major oil-recovery mechanism.

It has been found that usually the movement of water is slow, therefore requiring a severe measure of restriction of oil-withdrawal rates. Many fields of the United States are currently utilizing water drive to a high degree by limiting oil withdrawals to about 3 to 5 per cent per year of the ultimate yield.

The great East Texas field is a good example of this type of reservoir. By limiting net fluid withdrawals to rate of water movement into the structure, the reservoir pressure has been maintained over a period of years. Through this control not only will the ultimate recovery be substantially increased, but the cost of recovery is materially less, the effect of which is lower cost gasoline in the consumer's tank.

Wide recognition of the effectiveness of water drive has prompted operators to explore the possibilities of artificially stimulating this mechanism by injecting water around the flanks of the oil reservoir at an early date before original pressures have been reduced. This practice is a new development, but results are so encouraging it may be adopted wherever physical conditions permit.

In practice probably no one of these three drives will apply exclusively for the complete life of the field, but the degree of which one or another is utilized will have direct bearing on field behavior and ultimate oil yield. Both reservoir characteristics and operating control greatly influence the degree to which a particular drive is operative and hence influence the recovery expectancy. The problem in its simplest terms is to maintain the natural pressure in a reservoir so that the maximum amount of oil will be produced through natural forces. Control of these natural forces not only enables a much greater total recovery of oil but adds materially to the flowing life of the wells, thus reducing the cost of production.

Optimum Producing Rate. It is believed that, in most fields utilizing water-drive or gas-displacement mechanisms, the slower the rate of production, the greater the possible ultimate yield of oil. Reduction in rate below a certain level, however, will result in only insignificant increase in recovery, and it is customary to refer to this level as the "efficient rate." At rates of production above the efficient rate, ultimate recovery may drop off rapidly with increase in rate. The rate of production beyond which loss in recovery becomes appreciable is commonly referred to as the "maximum efficient rate" or "optimum rate."

CONTRIBUTION OF TECHNOLOGY TO INCREASED RECOVERY

From the foregoing discussion it will be obvious that technological advances have contributed substantially to our petroleum resources. Estimates in terms of barrels are of course difficult to arrive at, and because of the many factors involved such estimates are at the best only good approximations.

It has been conclusively demonstrated by actual field data that uncontrolled producing rates fail to recover as much oil as could be obtained by efficient reservoir operation. The loss varies widely and is dependent upon the characteristics of the individual reservoir and its contained fluids. As water is a more efficient displacing agent than gas, it may be expected that water-drive fields will obtain higher recovery than gas-drive fields, even though both are produced efficiently. From field experience it appears that water-drive reservoirs may be expected to recover under inefficient practices as much as 90 per cent of the recoverable oil if conditions are extremely favorable and perhaps only 60 per cent of the recoverable oil under less favorable conditions. In gas-drive fields the loss in recovery due to inefficiency varies over a much wider range and under the most adverse conditions recoveries may be only 30 per cent of the maximum obtainable

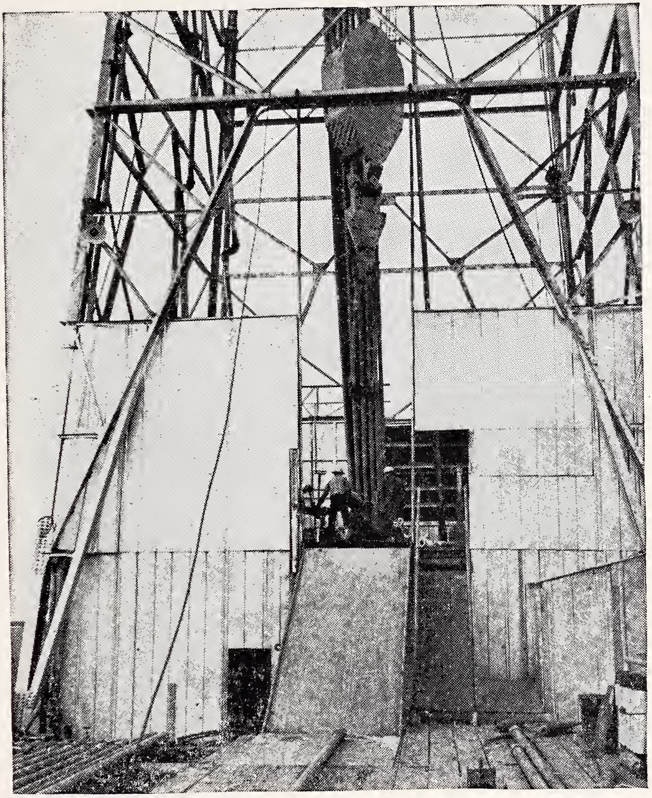

Fig. 52. World's deepest well—over 20,000 ft down. Superior Oil Co. wildcat well, Pacific Creek, Wyo. Pipe rack and derrick floor of the 150-ft drilling rig, the largest in the world.

and under the most favorable conditions may be as high as 80 or 90 per cent of the maximum possible recovery.

One field in southern Louisiana was losing 1 lb of reservoir pressure for every 3,650 bbl of oil it produced. Then the operators began to return gas to the pool to maintain pressure. That field is expected to yield at least 40 per cent more oil than it would have withour conservation.

The East Texas oil field—the largest ever found in the United States—suddenly went to water after its discovery in 1930. By injecting a substantial portion of the produced water and by limiting the net fluid withdrawals to the rate of water movement into the structure, the reservoir pressure of the field has been maintained over a period of years. A year after its discovery, East Texas was expected to produce no more than 2 billion barrels of oil. Since then it has yielded more than that amount—and its remaining reserves are now estimated at about 3 billion barrels.

Well Spacing

The question of well spacing is an important consideration in planning the development of a newly discovered field. The subject of well spacing and its possible effect on ultimate recovery has been studied and discussed over a period of many years. While it has been a highly controversial question, sufficient field data are now available to permit drawing certain conclusions.

It is generally agreed by most engineers that under modern production practices well density, or the distance between wells over the range of spacings normally employed, has little effect on the theoretical maximum recovery of oil. Proper well location and operation are, however, highly important. Well spacing, or the number of wells, obviously has a bearing on the time required for depletion of the field and is therefore an economic factor of great importance. The cost of producing the oil bears a direct relation to the number of wells through which the oil is recovered, and thus well spacing is one of several factors which determine the economic life of a field.

The time factor must be taken into account in deciding the well-spacing program, and sufficient wells must be drilled so that the amount of production withdrawn from each well is not excessive and will not result in the coning of water into the well or excessive channeling of gas. On the other hand, drilling too large a number of wells must be avoided, since in such cases the economic pressure to produce individual wells at rates which yield desirable returns on the investment may cause excessive or inefficient rates for the field as a whole. No over-all rule can be established for well spacing, as each field represents a different problem and the optimum spacing for a particular field must be determined on the basis of the characteristics of that field. In accordance with efficient production methods some pools may have only one well for each 40 acres, and spacing as wide as one well to 80 or 160 acres may be indicated. But 20-acre spacing in one pool may be as sound as 40-acre spacing in another. In general the industry has been tending in the direction of wider well spacing, and this trend was greatly accentuated during the Second World War because of the shortage of materials and man power.

The industry's trend toward wider well spacing is not without benefit to the public. Wider spacing, coupled with efficient operating practices, has made possible the same ultimate recovery with considerably fewer wells and thus a much lower investment on the part of the producer, which is reflected in lower producing costs. Thus, findings of the technologists on the effect of well density on recovery are of definite benefit to the consumer.

Condensate Fields

Deeper drilling in recent years has resulted in the discovery of a new type of petroleum accumulation known as "distillate" or "condensate fields." This type of accumulation exists in the gaseous form under the conditions of temperature and pressure prevailing in the reservoir, but, in contrast with conventional gas fields, a portion of the gas condenses as liquid upon reduction of pressure. For maximum recovery from this type of accumulation it is therefore necessary to maintain reservoir pressure above the point at which condensation takes place; failure to do this renders a substantial part of the liquid components unrecoverable.

The phenomenon of condensation upon reduction of pressure is known as "retrograde condensation" and has been the subject of considerable research. Knowledge of this peculiar behavior of the reservoir fluids has resulted in the development of a new producing technique known as "gas cycling." In this method of operation the reservoir fluid is produced in the gaseous phase, the liquid constituents are recovered at the surface, and the dry gas is compressed, is returned to the producing formation, and serves to maintain the reservoir pressure, thus preventing condensation in the formation. The result of this practice is substantially to increase the ultimate recovery of petroleum from reservoirs of this type.

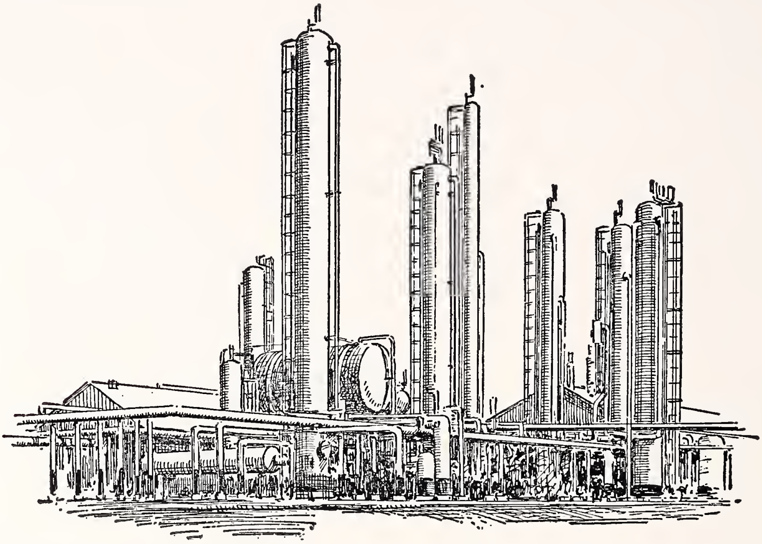

Fig. 53. Modern cycling plants extract petroleum condensates from natural gas and then return the gas to the reservoir to maintain pressure at the level necessary for maximum recovery. (*Petroleum.*)

Secondary Recovery

Producing practices employed in the early years of the industry, before scientific enlightenment, resulted in depletion of the reservoir energy before depletion of the oil, thus leaving a high percentage of the oil in the ground without natural propulsive energy. Modern research has demonstrated that much of this remaining oil can be recovered by supplying extraneous energy to drive the oil to the bottom of the well bore, from which it can be pumped to the surface. Water, air, and gas have been injected into old reservoirs for this purpose and have thus stimulated recovery; this operation is known as "secondary recovery." Secondary recovery is applicable primarily to fields produced by dissolved-gas drive or by inefficient gas-cap drive. Initiation of secondary-recovery practices need not await the decline of the producing rate to the economic limit and in most cases is initiated prior to that time.

Secondary-recovery practices have been adopted in a large number of fields in the United States and have already resulted in the recovery of millions of barrels of additional oil. Water flooding has been used most extensively in the Bradford area of Pennsylvania, where large quantities of additional oil have been recovered from fields which had reached their economic limit perhaps twenty-five years ago. Water flooding has also been used quite extensively in New York and in several of the other oil-producing states. Gas is probably the most commonly used injection medium in secondary-recovery operations and has been used in practically all of the producing states. Air is used only in cases where gas is not readily available, and the operation is not suitable for water flooding.

In most instances secondary-recovery operations are more costly than primary operations, and the method has therefore been used to date only in the most promising cases. Future technological improvements in secondary-recovery methods and a higher price for oil will no doubt cause its application on a much wider scale than at present. The portion of additional potential reserves which is recovered will depend somewhat upon the price of oil, but at least several billion barrels will be recovered when the public needs it badly enough to pay for it.

Mining of Oil Sands

The mining of oil sands has been limited in this country to one or two pilot operations which have been unsuccessful from the commercial point of view. Mining operations have been successfully carried on for a number of years in a few places in Europe. No doubt semimining methods depending on a shaft to the oil horizon, with many small lateral bores into the oil sand for drainage of oil into the shaft, will precede direct mining of oil sands. Here again, price is the determining factor, and many billions of barrels of oil can thus be recovered when conditions warrant.

Conclusions

It is seen that since the end of the First World War, the petroleum industry has made tremendous progress in the technology of gaining access to, and obtaining maximum recovery of, oil from underground reservoirs. As has been indicated, these advances in the science of petroleum production have added billions of barrels of oil to the recovery ultimately expected from present proved fields. Looking at it another way, the United States many years ago would have been unable to meet even its domestic requirements had it not been for the reserves made available by technological advances in drilling and producing.

In addition to the present estimate of 23-billion-barrels reserves from proved fields, other billions of barrels of oil, devoid of the energy necessary to bring it into the well bore, remain in the reservoirs of fields that have been depleted of their natural energy.

State conservation laws have been extremely helpful in furthering the application of improved producing practices, and the continuation of such laws is essential; those states which do not have such laws at present should adopt and effectively enforce them. However, the fullest attainment of technological advances requires more than compulsion by law; there must be an urge on the part of industry and the individuals who compose it constantly to improve the efficiency of their operation. The dissemination of information and technical knowledge through the forum of industry societies and associations and through the Interstate Oil Compact Commission should be continued. This last state and Federal mechanism, if properly implemented by government and industry, can render great service to the industry and to the nation.

The recovery of oil from the deep-seated strata of the earth's surface is a highly scientific and complex problem. Great progress has been made in our knowledge of the behavior of these accumulations in the past quater century and of the factors which control the recovery of oil from the subsurface storehouses. There is every reason to believe that technological knowledge, if permitted to advance, will enable the recovery and utilization of a continuously greater proportion of these deposits in the future.

The technological advances which have been made in the United States can be directly attributed to the American way of life. Creativeness cannot be forced or regimented but must be nurtured in the sunshine of free enterprise. A sound national oil policy requires that the atmosphere conducive to greatest technological development be preserved, as this is the great multiplier of our national resources.

Chapter VI

OUR OIL AND NATURAL-GAS RESOURCES

Part 1. THE EARTH'S PETROLEUM RESOURCES[1]

By Wallace E. Pratt, *Consulting Geologist*

Perhaps the most significant developments in the petroleum industry since the publication of the first edition of this study in 1945 are (1) the great increase in world demand for petroleum products—an increase much larger than was generally anticipated —and the even larger increase in production consequent upon it; (2) a growing realization that petroleum is rather commonly entrapped in the earth's crust, in areas other than those which have supplied most of our needs in the past; (3) the mounting interest in the potentially very large petroleum resources of the continental shelves of the earth; and (4) the effect of the great increase in world demand for liquid fuels in stimulating and quickening our interest in techniques for deriving liquid fuels from solid hydrocarbons such as coal, oil shale, and tar sands.

When the first edition of this book appeared, the world had consumed 44 billion barrels of petroleum; at the end of 1947 world consumption had amounted to nearly 55 billion barrels. In 1940 the annual rate of consumption, world wide, was 2 billion barrels; in 1947 it was 3 billion barrels, an increase of 50 per cent. In the United States, consumption of petroleum products increased from 1.3 billion barrels in 1940 to 2.2 billion barrels in 1947.

At the end of 1940 crude-oil production in the United States had reached a level—amazingly high to those who had followed the fortunes of the oil-producing industry over the period intervening between the two world wars—of 3.6 million barrels daily. At the beginning of the Second World War production had risen still further to a level of 4.1 million barrels daily. Prices were frozen when war began, and production was controlled to fit into the wartime economy. At the end of the war it stood at about 4.9 million barrels daily, and industry felt that it had performed a Herculean task in meeting all war demands fully.

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[1] The author is indebted to his former associates on the staff of the Standard Oil Company (New Jersey) for invaluable counsel in the preparation of the estimates and statistics in this paper.

With the end of the war, demand slumped, and production decreased in consequence to 4.3 million barrels daily in the latter months of 1945. Almost immediately, however, as the work of reconstruction gathered momentum, demand again began to increase, and by the middle of 1946, to everyone's astonishment, production reached a level higher than the wartime peak. Industry was driven to the utmost to meet demand.

At this juncture, crude-oil prices, which were still held at the inadequate depression level where they had been frozen when war struck us (average East and West Texas, about $1.10 per barrel at the well), were freed from controls and began a rapid increase which carried them to the present level (average East and West Texas, about $2.20 per barrel at the well by the end of 1947).

With increased prices came still further increase in production to the present incredible figure of 5.6 million barrels daily.

Along with domestic production world production of crude oil has also increased phenomenally since 1940 (from 5.6 million barrels daily in 1940 to 9.2 million barrels daily in 1948). And the end is apparently not yet in sight. Competent observers anticipate a total world production of more than 11 million barrels daily within the next five years.

Since the first edition of this book was published, the Prairie Provinces of Canada have finally been proved by repeated actual discoveries to contain great oil fields—oil fields which may be related in origin to the Athabaska tar sands, the greatest accumulation of petroleum on earth—and the productive areas seem likely to be distributed over the entire region from the southern boundary of Canada to the coasts of the Arctic Sea, a distance of more than 1,500 miles. Similarly, Chile has made two discoveries of new oil fields at the other extremity of the land mass of the Western Hemisphere, at the southern tip of the continent of South America.

Simultaneously, oil and gas have been developed in southern France, and a commercial oil field has come into production in the Netherlands. It is becoming more evident to everyone that western Europe is not truly a region of "have-not" nations so far as indigenous petroleum resources are concerned, as has generally been assumed in the past. These resources may not be large, but they do exist. The enormous potentialities of Russia and Siberia for petroleum production have become more clearly visualized, and the Middle East has expanded still further the vast proved reserve it had developed when the Second World War opened.

Proved petroleum reserves, world wide, which were estimated at 50.7 billion barrels in 1944, had risen to 69.3 billion barrels at the end of 1947. And this increase had taken place in the face of an unprecedented consumption of some 7 billion barrels over the intervening three years.

The calculations and estimates in this paper take no account of the possible petroleum resources of the continental shelves of the earth. The proved reserves and total petroleum resources here discussed are those of the present land areas of the earth. Yet it is reasonable to believe that the processes which generate and entrap commercially important accumulations of petroleum have been even more active in the region of the continental shelves than in the sediments deposited in seas which periodically overflowed the more stable continental platforms, constituting the present land areas. With the growing importance of petroleum to society and consequent anxiety as to the adequacy of our total petroleum resources, the potentialities of the continental shelves have commanded increasing interest and study.

The continental shelves are the sea floors beneath the belt of marginal shallow waters which surround the continents. They occupy an intermediate position between the deep oceanic basins proper, from which they are separated by the steep continental slopes, and the high continental platforms. The usual definition states that the term "continental shelf" is "arbitrarily" limited to the sea floor beneath marginal waters not exceeding 100 fathoms (600 ft) in depth. It is worth while to observe that this limitation is not, in fact, "arbitrary"; it is, on the contrary, wholly logical. We should bear in mind that the continental platforms are perched on high, steep-sided earth welts. The present volume of the deep oceanic basins is such that their waters rise above their edges to submerge the outer part of the flat continental margins. This submerged continental margin is the continental shelf. Its outer edge marks the brink of the steep continental slope which descends into the oceanic basins proper. Its outer edge also marks the depth limit of effective wave action on the sea floor, together with the limit to which sunlight penetrates below the surface of marine waters.

The aggregate area of the continental shelves of the earth is 11 million square miles. Of this total, about 1 million square miles is contiguous to the coasts of the United States, including Alaska. The most conspicuous development of the continental shelf is in the great mediterranean regions of the earth; the European mediterranean lying between the continents of Africa, Europe, and Asia; the American mediterranean, the waters of the Caribbean Sea and the Gulf of Mexico, occupying the down-warped basin between the continents of North and South America; the Asiatic mediterranean, the island-studded and essentially landlocked seas of Oceania, lying between the continents of Asia and Australia; and the Arctic mediterranean, occupying the depression at the North Pole, bordered by the continents of North America, Europe and Asia. Within these four regions is developed more than 50 per cent of the total area of the continental shelves.

The continental shelves are in part built up of the debris of soil and rock fragments weathered and eroded from the surfaces of the continents and carried into the sea by wind and flowing water. In part, they consist of the residue of marine organisms and chemical precipitates which sink to the bottom and are buried on the floor of the sea. Practically all of the debris from the continents which is carried as sediment out into the sea comes to rest on or at the edge of the continental shelf. Beyond this limiting depth, wave and current action fail to move it, and almost none of it reaches the oceanic basins proper.

Umbgrove[2] has shown the continental shelves to be regions of spasmodic down warping and compensatory uplift of the earth's crust, the zone along which stresses in the earth's crust relieve themselves; they are mobile segments intervening between the elevated, lightweight material of the continental platforms and the heavy, depressed ocean floors. Dramatic evidence of the down-warping tendency of this zone of stress adjustment is to be observed in the profound deeps which commonly lie at the outer edge of the shelf. In this position are to be found the lowest parts of the ocean floors.

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[2] UMBGROVE, J. H. F., Origin of the Continental Shelves, *Bull. Am. Assoc. Petroleum Geol.*, Vol. 30, No. 2, pp. 249–53, February, 1946.

In addition to their extreme mobility the continental shelves are an efficient, automatically functioning mechanism for sorting and classifying the sediments which rain down upon them. Sands are separated from clays, according to grain size. Wave action leaves coarse materials only on the eminences of the shelf surface and carries the fine-grained clays (which consist largely of organic remains) away to drop them into the basins or down-warped portions of the shelf.

Finally the continental shelves are preeminently the habitat of marine life, the accepted source material of petroleum. Authorities agree that the shallow waters overlying the continental shelves support much more life than an equal area of normal deep-sea waters. Lohman[3] is convinced that coastal waters, on the whole, are fifty times more productive of life than the open sea.

The primary source of food for marine life is plankton, microscopic plants which abound in surface waters. Utilizing the energy of sunlight, these tiny plants convert inorganic salts into food for themselves and, in turn, for all the animal life of the sea. They thrive where upwelling waters bring to the surface the inorganic residues, including the plant nutrients, nitrates, and phosphates, which normally accumulate on the sea floor. Trask[4] explains the abundance of plankton and other marine life on the continental shelves, in part, by the upwelling of bottom waters along the steep wall of the continental slope at the outer edge of the shelf.

The conditions we believe to be favorable to the generation of petroleum in large volumes include: (1) an abundance of organic source material; (2) an abundance of other sediments; (3) deposition of source material with other sediments of varying grain size, rapidly, in saline waters; (4) the classification of fine and coarse sediments according to grain size and the separation of the muds from the sands; (5) the segregation and deep burial beneath other sediments of the organic material (characteristically a fine-grained mud) in an environment which both prevents the normal process of oxidation and excludes the scavengers common to the ordinary sea floor. Wave action on shallow bottoms has been observed to be an efficient natural agency for classifying and segregating sediments according to grain size, and the stagnant, foul waters which fill the deeper parts of the closed basins formed by the sharp down warps in a mobile sea floor are known to prevent oxidation and to be poisonous to marine scavengers.

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[3] H. Lohman quoted by H. V. Sverdrup, Martin W. Johnson, and Richard Fleming, "The Oceans," p. 763, Prentice-Hall, Inc., New York, 1942.

[4] Trask, Parker D., Organic Matter in Recent Sediments, "Problems of Petroleum Geology," American Association of Petroleum Geologists, 1934.

We believe the accumulation of petroleum and its preservation in large volumes in natural reservoirs underground takes place with the progressive compaction under the weight of an increasing load of overlying sediments, of the organic muds described in the preceding paragraph, and the escape of the contained fluids, including oil and gas, from these muds, under compaction, into the open pore spaces of adjacent mud-free sand lenses, or bars, or limestone reefs.

The continental shelves of the earth fulfill these specifications admirably—better than any other part of the earth's crust. They are mobile, and their periodic down warping accentuates erosion and maximizes the deposition of sediments. Along the outer edge of the shelf, upwelling currents, laden with plant food, stimulate marine life to unparalleled abundance. Profound down warping forms the deep closed basins—the veritable septic tanks—in the stagnant, deeper waters of which no scavenger lives and only reducing (nonoxidizing) conditions prevail. Sweeping across the surface of the shelf, waves and currents separate fine sediments from coarse, build the latter into bars of porous, clean sands, and carry the former—which are largely organic residues—off to drop them into adjacent closed basins, where they come to rest, out of the reach of further wave or current action. Under these conditions there is maximum opportunity for the fluids, squeezed out of the organic muds and oozes in these closed basins by the weight of overlying sediments, as these accumulate, to move upward and outward into the open spaces of the porous reservoir beds which are a part of the adjacent shelf floor.

The foregoing reflections lead us to classify the sediments of the continental shelves as better adapted to house great stores of petroleum than the average series of sedimentary beds laid down in the transitory seas which, from time to time, have spread over the more stable continental platforms. The volume of the sediments on the continental shelves, also, is greater than the aggregate volume of the marine sediments which form part of the present land surface. We do not have precise estimates of the volume of the continental-shelf sediments, but if we accept the approximations of Twenhofel,[5] the father of the science of sedimentation, we might conclude that the volume of the sediments favorable for petroleum resources in the continental shelves is of the order of 50 million to 60 million cubic miles. Within present land areas, the total estimated volume of sediments of this character is of the order of only 20 million cubic miles.[6]

These figures are approximations only, but they indicate a much greater load of marine sediments on the continental shelves than on the more stable continental platforms. The volume of marine sediments of favorable character within the boundaries of the United States can hardly exceed 3 million cubic miles. In these sediments we have already found some 57 billion barrels of oil. If the sediments of the Continental Shelf are an equally favorable environment for petroleum resources and are twenty times larger in volume, they must contain a great store of oil.

The exploration of the Continental Shelf for petroleum has already been initiated. Off the shores of three states—Louisiana, Texas, and California—oil is already being produced from wells drilled into the sediments of the Continental Shelf. Out of the first 10 exploratory wells drilled off the Gulf coast, 7 have been successful—an astonishingly high rate of discovery when compared with operations on land, where it is unusual to record more than 2 successes out of each 10 exploratory wells drilled.

This experience tends to confirm our speculations about the favorable character of the sediments of the continental shelves as hosts for petroleum resources. Nevertheless, we should beware of exaggerated hopes of recovering great volumes of petroleum from the continental shelves. The difficulties and the costs of carrying on producing operations over deep water are tremendous —and the technical problems are by no means solved. However much oil there may be under the continental shelves of the earth, it is of little value to society unless it can be "reduced to possession" at tolerable costs.

In the past the United States has supplied most of the oil the world has used. Over a period of 30 years, from 1860 to 1889, we furnished 85 per cent of the world's consumption. Up to the end of 1947 about 64 per cent of the total had come from this country. Since 1860 only Russia has ever surpassed the United States in petroleum production, and her supremacy endured only over the last 4 years of the nineteenth century. How does it come about that our country has been the source of so large a part of the world's oil? Are our total supplies so much larger than those of other nations? Where are the principal petroleum resources of the world situated?

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[5] Twenhofel, W. H., "Treatise on Sedimentation," pp. 860*ff.*, Williams and Williams, 1932.

[6] Weeks, L. G., Basins and Oil Occurrence, unpublished report to Standard Oil Company (New Jersey), New York.

If we are to pursue these inquiries, it will be helpful at the outset to establish a few reference points from which we can proceed without becoming confused. The history of the petroleum industry goes back about ninety years. While we like to believe that the world's commercial production of petroleum began with the completion of Colonel Drake's first well at Titusville, Pa., in 1859, it is probably more realistic to concede that Rumania's production of about 2,000 bbl in 1857 marked the inception of the modern industry. Canada first produced oil commercially in 1862; Russia, in 1863.

The world's total consumption of petroleum through 1947 amounts to 54.8 billion barrels; and the 1947 rate of world consumption was somewhat more than 3 billion barrels a year, or 8.2 million barrels daily. The United States alone has consumed 35.0 billion barrels of petroleum up to the end of 1947, and its domestic consumption in 1947 was 2.2 billion barrels, or 5.4 million barrels daily. Thus we have been by far the largest consumer of petroleum among the nations as well as the largest producer, with a total consumption approximately equal to our own total production.

Petroleum is a mineral fuel—solid, liquid, or gaseous in form—consisting of many different compounds of hydrogen and carbon (hydrocarbons) in complex mixture. It is widely disseminated in the earth's crust, and it exudes from the earth's surface as natural seepages at many places. Its observed occurrence is almost exclusively confined to the marine sedimentary rocks (rocks formed through the slow compaction and hardening of mud, sand, and dust carried into the sea from the adjacent lands by streams and winds and deposited as sediments on the sea floor). Because of its constant association with these rocks and because of the facility with which the organic matter of marine sediments can be converted into hydrocarbons both in nature and in the laboratory, petroleum is usually considered to have its origin in the organic matter of marine sediments. It is well established, however, that hydrocarbons are present in the stony meteorites which come to us from space,[7] and astronomers have identified methane, the most common hydrocarbon of petroleum, in the atmospheres of the planets Saturn and Jupiter, where it appears to be present in abundance. It is not surprising, therefore, that hydrocarbons are widespread in the earth's crust.

Time after time in the past, the seas have spread over the margins and even the central parts of each of the continents. Into these seas great loads of sediments have been carried by streams flowing off the lands which still stood above sea level. When the continents reemerged from the sea, these sediments became dry land and hardened into rock. Marine sedimentary rocks of this character constitute more than one-third of the land surface of the earth, forming a total area of 22 million square miles. The United States alone, with a total area of 3 million square miles, includes 2.4 million square miles of sedimentary rocks. Of this area, however, only about 60 per cent (1.4 million square miles) may be expected to contain oil fields; the remainder (1 million square miles) is eliminated from consideration for various reasons: the original organic content was too low; or the deformation and induration subsequent to deposition have been so severe as to destroy the pore spaces of the rocks along with whatever petroleum they may have contained.

While almost any porous rock layer contains some petroleum, experience has taught us to expect large accumulations in sediments that were deposited rapidly and in great thickness. Rocks which are known to conform to these specifications and are, therefore, distinctly favorable for the occurrence of petroleum form an aggregate area of 900,000 square miles in the United States and of about 6 million square miles over the earth as a whole. Thus the land area already known to be distinctly favorable for petroleum totals about 6 million square miles, 15 per cent of which lie within the United States.[8]

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[7] Clarke, Frank Wigglesworth, "The Data of Geochemistry," p. 746, Government Printing Office, Washington, D.C., 1924.

[8] These areas have been compiled by my associates, Eugene Stebinger and L. G. Weeks, "Oil in the Earth," p. 47 to p. 164, University of Kansas Press, Lawrence, 1942.

Sediments accumulate in sufficient thickness to house large petroleum reservoirs only where the sea floor on which they are laid down subsides as the load increases; otherwise, the sea fills up and sedimentation comes to an end before the requisite thickness is attained. Parts of each of the continental platforms have been covered by seas in the past, but as we have already noted, the more mobile region of the continental shelves has been more constantly submerged. Unusually favorable are those depressed mobile sectors of the earth's crust which lie between the main continental land masses. Throughout much of geologic time these intercontinental depressions have been occupied by landlocked seas, as, indeed, they are today. Over long periods these seas have teemed with marine organisms, which upon dying were promptly carried to the bottom and buried in the flood of sediments pouring in from the adjacent lands. These are the conditions which, we believe, give birth to petroleum.

If we examine the intercontinental depressions now marked by landlocked seas on earth, we are confronted at once with our principal petroleum provinces. An example is the Mediterranean region of the Old World—low-lying lands (parts of them even below sea level) surrounding the Persian Gulf, the Black, Caspian, and Red Seas, and the eastern end of the Mediterranean Sea—a depressed, uneasy sector of the earth's crust, caught between the continents of Africa, Europe, and Asia. Here are the tremendous oil fields of the Middle East—those of Iran, the adjacent U.S.S.R., Iraq, and Arabia.

In the Western Hemisphere a great basin occupied by the Gulf of Mexico and the Caribbean Sea lies between the continents of North and South America. The lands which border these waters rank second among the petroleum provinces of the earth, both in proved reserves and in promise for future discoveries. This province includes Colombia, Venezuela, Trinidad, Central America, the West Indies, Mexico, and, in our own country, the states of Florida and Louisiana, together with parts of Georgia, Alabama, Mississippi, Arkansas, and Texas.

There are already many important oil fields in the environs of the Gulf of Mexico and the Caribbean Sea. In past production and in its present producing rate this province surpasses even the Near and Middle East. Exploration is further advanced in the Western Hemisphere than in the Near and Middle East, however;

and although neither province has been explored with any degree of thoroughness, the Middle East appears to offer better chances for additional discoveries susceptible of low-cost recovery.

Another region which has already furnished a significant part of the world's petroleum and promises to become a more important producer in the future is Oceania, situated in the Far East. It includes the great islands of the East Indies—New Guinea, Java, Sumatra, and Borneo—which rise out of the shallow landlocked waters between the continents of Asia and Australia. On these islands British and Dutch companies have been producing oil for 50 years. American oil companies established themselves there much later but now occupy a position which approaches that of each of the other two nations. Exploration of this region is still in its initial stages, and the potentialities for future production are not generally recognized.

There remains to be noted a fourth region of landlocked intercontinental seas which may yet become one of the earth's important petroleum provinces, namely, the lands surrounding the Arctic Sea. We usually think of the waters covering the North Pole as the Arctic Ocean, but they really constitute a sea, lying between, and all but surrounded by, the continents of North America, Europe, and Asia. Throughout most of geologic times, sediments have been dumped into the Arctic Sea by the rivers draining each of these great land masses. Conspicuous seepages of oil and gas mark northwestern Canada, northern Alaska, and, at intervals, the entire northern coast of Siberia. In this region, therefore, we have a zone 4,500 miles in length which is studded with seepages of oil and gas. Despite all this surface evidence of the presence of petroleum, the only persistent effort to develop a source of petroleum in the Arctic of the Western Hemisphere has been confined to the vicinity of Fort Norman on the lower Mackenzie River in the Northwest Territory of Canada, where a major oil field has been proved.

In the distribution of petroleum in the earth's crust, as revealed by the geographical position of the four great petroleum provinces, there is a striking accommodation to the principal centers of population and consumption. The most imposing province, the Near and Middle East, is conveniently placed to serve the great industrial population of Europe as well as the peoples of Africa and Asia. The Soviet Union has her own indigenous sources of supply. North and South America both may draw expeditiously on the Caribbean–Gulf of Mexico region. In the Orient the resources of the East Indies are centrally located between Australia and Asia. To the peoples of both hemispheres the potential resources of the Arctic will be available as civilization moves northward.

There are numerous minor basins of sedimentary deposition on the continental shelf around the margins of all the continents. The seas which filled these basins have at times extended far inland, and in the rocks formed in these old seas much petroleum has been discovered. The important oil fields of California and of the interior basins of the Mississippi Valley are examples, as are also the oil fields of Bolivia and Argentina in South America; of Germany and Poland on the margin of the Baltic Sea; of Austria and Hungary in central Europe; of Burma; and of Japan, Sakhalin, and Kamchatka around the Seas of Japan and Okhotsk off the Pacific coast of northeastern Asia. In central Siberia and in northwestern China are other interior basins, the rocks in which are known to be petroleum-bearing. Outside of the United States, however, these smaller basins remain largely unexplored and so far have yielded but a small part of the world's petroleum.

Table 1 shows the past production, the current rate of production, the proved reserves, and the probable ultimate petroleum resources of these and other producing regions. This table takes no account of natural-gas resources, which in the United States appear to be about equal in energy content to petroleum resources.

The United States is fortunately situated in relation to the petroleum resources of the Caribbean–Gulf of Mexico region and will also share largely in whatever petroleum reserves are developed in the Western Hemisphere sector of the Arctic province. Within the borders of our sister nations to the south—Mexico, Colombia, Brazil, Ecuador, and Peru—we have identified great sedimentary basins, marked by seepages of oil and gas, which are all but unexplored, although similar adjacent basins already contain important oil fields. Without industrial resources, such as oil-field experience and machinery, organization, technical skills, and capital, the development of these resources must be long delayed. Shall we not, under agreements which safeguard the national interests of our neighbors, place at their service our special qualifications for making these resources available for the common good? Surely it would be mutually advantageous if Latin Americans sent to us any exportable surpluses of petroleum which may be developed in their countries in exchange for our manufactured goods.

Our stake in the petroleum resources of the Arctic is Alaska, which includes a large part of the most promising area and some of the most impressive oil seepages. Thousands of square miles surrounding oil seepages near Point Barrow on the extreme northern coast of Alaska were set aside more than twenty years ago as a petroleum reserve for the United States Navy. An adjacent, even larger, and equally promising area is controlled by the Secretary of the Interior. Alaska is almost virgin territory as far as well drilling is concerned. Therefore it finds no place in any present compilation of the earth's proved reserves of petroleum. Nevertheless, exploration in Alaska will almost certainly prove the existence of large reserves.

TABLE 1. TOTAL PAST PRODUCTION THROUGH 1947
Rate of Production, Proved Reserves, and Probable Total Ultimate Resources, Excluding Continental Shelves

Country or region*	Production				Proved reserves		Total ultimate resources	
	Total past		1947		Bbl†	%	Bbl†	%
	Bbl†	%	Bbl‡	%				
United States	35.0	64	5.1	61	22.0	31	100	17
Gulf of Mexico–Caribbean area	20.1	37	4.3	52	23.2	33	117	20
Western Hemisphere	43.1	79	6.7	81	31.1	45	210	35
Russia and Siberia	5.8	11	0.5	6	6.0	9	150	25
Middle East	2.4	4	0.8	10	30.0	43	150	25
Oceania	1.2	2	0.1	...	1.2	2	35	6
Eastern Hemisphere	11.7	21	1.6	19	38.1	55	390	65
World	54.8	100	8.3	100	69.3	100	600	100

* Gulf of Mexico–Caribbean area includes the Gulf coast province in the United States, Trinidad, Venezuela, Colombia, Central America, Mexico, and the West Indies. Middle East includes Iran, Iraq, and Arabia. Oceania includes the British and Dutch East Indies in the Far East.

† Billions of barrels.

‡ Millions of barrels daily.

While the U.S.S.R. has furnished only 11 per cent of the world's past production and holds only 9 per cent of the world's proved reserves, it possesses within its own borders more imposing potential resources in petroleum than any other nation. Its proved reserves are small (as we estimate them; Soviet engineers claim much larger proved reserves), and its capacity to produce is even less adequate (600,000 bbl daily, as compared with 5.5 million barrels daily in the United States); but these deficiencies result from lack of development. The aggregate area characterized by seepages of oil and gas in the U.S.S.R. is immense; it includes a major part of both the Middle East and the Arctic petroleum provinces. The Soviet Union's principal oil fields are situated on the shores of the Caspian Sea in the Middle East, and much prospective territory remains to be developed in this region. But other oil fields mark the flanks of the Caucasus Mountains, and still others mark the western flank of the Urals, in a northward-tending zone that reaches clear to the Arctic coast, a distance of 1,500 miles. Throughout Siberia there are evidences of petroleum: natural seepages along the Arctic coast in northern Siberia and at many places in the great basin drained by the Lena River in eastern Siberia; partly developed oil fields on Kamchatka Peninsula and Sakhalin Island on the shores of the Sea of Okhotsk in the Far East; and finally, abundant evidences of oil and gas over a distance of more than a thousand miles through Turkestan and along the southern border of Siberia. In all these regions Soviet engineers were engaged in exploration and development work when the war broke out, apparently bent upon making the U.S.S.R. self-sufficient as to liquid fuels.

The position of the Soviet Union illustrates the fallacy of citing proved reserves as a measure of available future supplies in the present state of development of the earth's petroleum resources. With far smaller proved reserves than the United States, the Soviet Union is at the same time generally conceded to be more nearly self-contained as to petroleum than any other nation. Her position illustrates the fact that so large a part of the probable petroleum resources of the earth remain still undeveloped that the volume of the proved reserves has little significance.

If, then, we discard proved reserves, what evidence can we cite as an index of the amount of petroleum that will be available to us in the future? Probably the best guide we have is a projection into the future of the trends established by our past experience in the search for petroleum. Over the last 85 years we have drilled more than a million wells in the United States. Of the purely exploratory wells drilled, 10 to 15 per cent were successful in finding petroleum in commercial quantities. Of the total area definitively tested by drilling, 1 to 2 per cent proved to be commercially productive of petroleum.[9] In favorable sedimentary basins the productive portion is more than double this average.

If 1.5 per cent of the 900,000 square miles (577 million acres) of the distinctly favorable parts of the land area of the United States ultimately proved to be productive, as might reasonably be expected on the basis of our total past experience, then we should eventually produce oil from 8.6 million acres of land, assuming only that exploration be carried to completion. Our present productive area (1948) is estimated at 4.5 million acres, from which we believe we shall eventually obtain 57.2 billion barrels of oil.

These conclusions would make the ultimate petroleum resources of the land area (excluding the Continental Shelf) of the United States of the order of 100 billion barrels, 65 per cent of which still remained in the earth at the end of 1947.

Because we have produced most of the world's petroleum in the past, we have assumed that our resources are unusually rich and that we have been blessed by nature with greater natural stores of petroleum than other nations. Today we realize that this is not true; the truly rich petroleum resources of the earth, so far as they have been discovered, lie outside our boundaries. We have nothing to compare with the Middle East, for example. When we review the evidence, it seems probable that the average petroleum content of the sedimentary rocks in the United States is about the same as that of the rest of the world.

Exploration for petroleum in the United States is extensive enough to make its findings significant. It has proceeded far enough to indicate what volume of petroleum may be discovered, on the average, by intensive drilling exploration of the sedimentary rocks of the earth. If we accept our oil-finding experience in the United States as representative, then the ultimate petroleum resources of the rest of the earth should amount to more than 600 billion barrels. On the same basis one would conclude that about 35 per cent of the earth's total petroleum resources lies within the Western Hemisphere.

What accounts for the fact that the United States has produced so large a part (64 per cent) of the oil the world has consumed in the past from so small a part (15 per cent) of the earth's total store of oil? I believe the answer lies in two circumstances: (1) Americans are, by nature, active, ingenious, resourceful, chance-taking pioneers. (2) Within the United States, Americans have been free to go about anywhere, everywhere, searching for oil and producing oil when they found it.

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[9] Stebinger and Weeks, *op. cit.*

Americans are prone constantly to strive to widen their frontiers. Even before they reached the limits of their horizontal, or geographical, frontiers, they began to explore their vertical, or geological, frontier. Our great production of petroleum within the United States results not so much from superior natural resources as from superior natural resourcefulness.

Our freedom from government and social restriction of the individual in the United States has permitted us to develop whatever natural resources we do possess rapidly and effectively. Nations which place ownership of mineral resources in the state, instead of the individual owner of the surface, deny the opportunity to explore and develop these resources to the great majority of their citizens. The small individual enterpriser can trade and negotiate with his neighbors for the right to drill wells in search for oil on their lands. But he is handicapped when he attempts to negotiate with the state itself. And in those nations which establish monopolies to administer their petroleum resources, the individual is even more effectively excluded from participation in the exploration of these resources.

The unparalleled success in discovering thousands of small, obscure oil fields, as well as great oil fields, in the United States has resulted from the drilling of hundreds of thousands of exploratory wells, the locations of which were determined independently by tens of thousands of different individuals, each guided by his own ideas of where oil might be found. No single agency—not even a government—could finance so extensive an exploration. No other method of exploration could take advantage effectively of so many clues and theories as to the occurrence of oil.

The mounting demand for liquid fuels, world wide, taken together with the increasing difficulty and higher costs which face the petroleum producer, whether he look to the remaining resources in the United States, or to the land areas of the rest of the world, or to the potential resources of the continental shelves, has accelerated industry's plans to substitute solid hydrocarbons—coal, oil shale, and tar sands—for petroleum, as sources of liquid fuels. Government is attempting to encourage this shift toward solid hydrocarbons as sources of liquid fuels by carrying on research on techniques and enacting special legislation designed to facilitate and hasten the progress of the transition.

Commercial plants for the synthesis of liquid fuels from natural gas are already under construction. Costs in these plants will be competitive with those for liquid fuels from petroleum.

Pilot plants are in operation which synthesize liquid fuels from coal, and plans for commercial units are being prepared. Very large capital outlay is required, however, and it is not yet possible to say that synthesis from coal is competitive with liquid fuels from petroleum.

Pilot plants are also being operated which produce from oil shale an oil from which gasoline and other liquid fuels can be manufactured by suitable refining processes. To establish a liquid-fuel industry using oil shale as a raw material also requires an enormous capital investment, however, as well as appalling expenditures of materials and man power, and a number of years will probably elapse before a large volume of liquid fuels is produced from oil shale in the United States.

Part 2. ESTIMATE OF UNITED STATES OIL RESERVES AND NATURAL-GAS LIQUIDS RESERVES

By THE AMERICAN PETROLEUM INSTITUTE

SUMMARY

Proved reserves of crude-oil and natural-gas liquids in the United States rose more than 2 billion barrels in 1948, the biggest 1-year increase in this vital resource in almost a dozen years. In a joint report by the American Petroleum Institute and the American Gas Association it was shown that proved reserves of natural gas went up almost 8 trillion cubic feet in the same 12-month period ending Dec. 31, 1948.

The annual reports on reserves were prepared by the reserves committees of both organizations. The crude-oil reserves were

estimated by the API committee and the gas reserves by the AGA group. The natural-gas liquids reserves (condensates, natural gasoline, and liquefied petroleum gases) were estimated by both committees.

The big increase in both hydrocarbon and natural-gas reserves provides the nation with a comforting backdrop for future progress. The committee reports involve only proved reserves of petroleum and natural gas. They are not concerned with the oil and gas yet to be discovered or the fields and areas where the potential is yet to be proved.

CRUDE-OIL AND NATURAL-GAS LIQUID

Date	Crude oil, bbl. of 42 gal	Natural-gas liquids, bbl of 42 gal	Total bbl of 42 gal	Natural gas, thousands of cu ft
		Reserves		
Dec. 31, 1947.	21,487,685,000	3,253,975,000	24,741,660,000	165,926,914,000
Dec. 31, 1948.	23,280,444,000	3,540,783,000	26,821,227,000	173,869,340,000
Increase 1948 over 1947......	1,792,759,000	286,808,000	2,079,567,000	7,942,426,000
		Production		
Dec. 31, 1947.	1,850,445,000	160,782,000	2,011,227,000	5,629,811,000
Dec. 31, 1948.	2,002,448,000	183,749,000	2,186,197,000	6,007,628,000
Increase 1948 over 1947......	152,003,000	22,967,000	174,970,000	377,817,000

The joint API-AGA report estimated the proved total liquid-hydrocarbon reserves in the United States at 26,821,277,000 bbl, an increase of 2,079,567,000 bbl over the 1947 total.

Production of crude-oil and natural-gas liquids in the United States was estimated at 2,186,197,000 bbl during 1948, an increase of 174,970,000 bbl over the preceding year, or 8.4 per cent.

Natural-gas reserves were estimated at 173,869,340,000,000 cu ft as of Dec. 31, 1948. This is an increase of 7,942,426,000,000 cu ft over the 1947 total. Production was estimated at 6,007,628,000,000 cu ft, an increase of 377,817,000,000 cu ft over the preceding 12 months.

The tremendous increase in liquid-hydrocarbon reserves was the first to exceed the 2-billion-barrel figure in any one year since 1937. The proved reserves increased 2,443,868,000 bbl in that year. This figure, however, represented crude oil only since natural-gas liquids statistics were not included at that time.

The reserves and production totals for 1948 were as shown in table on p. 154.

The production figures are net after deducting the amount of gas returned to reservoirs.

Report of the American Petroleum Institute's Committee on Petroleum Reserves

Your Committee on Petroleum Reserves herewith submits its annual report on proved liquid-hydrocarbon reserves of the United States as of Dec. 31, 1948. As will be recalled, beginning with our report for Dec. 31, 1946, the estimates presented on proved liquid-hydrocarbon reserves were expanded to include not only crude oil, but also all classes of natural-gas liquids. (See definition of natural-gas liquids as given by AGA committee in copy of its report beginning on p. 168.) The figures on crude oil were prepared by the AGA committee, in cooperation with the API committee. For the present report, the same procedure has been followed.

As of Dec. 31, 1948, the committee estimates that the proved reserves of crude oil in the United States amounted to 23,280,444,000 bbl. The natural-gas liquids totaled 3,540,783,000 bbl, making a grand total of liquid hydrocarbons of 26,821,227,000 bbl. This is shown in Table 2.

The estimates in this report, as in all previous annual reports of this committee, refer solely to proved or blocked-out reserves. They include only oil and natural-gas liquids recoverable under existing economic and operating conditions.

The estimates made for this report by your committee do not include:

1. Oil[10] under the unproved portions of partly developed fields
2. Oil in untested prospects
3. Oil that may be present in unknown prospects in regions believed to be generally favorable

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[10] The word "oil" unless defined as crude oil is used in this report as essentially equivalent to liquid hydrocarbons.

4. Oil that may become available by secondary-recovery methods from fields where such methods have not yet been applied
5. Oil that may become available through chemical processing of natural gas
6. Oil that can be made from oil shale, coal, or other substitute sources

TABLE 2

a. CRUDE OIL—API

(Barrels of 42 U.S. gal)

Total proved reserves of crude oil as of Dec. 31, 1947		21,487,685,000
Revisions of previous estimates	+ 1,958,853,000	
Extensions of old pools	1,439,873,000	
New reserves (new pools) discovered in 1948	396,481,000	
Proved reserves added in 1948		3,795,207,000
Total proved reserves as of Dec. 31, 1947 plus new proved reserves added in 1948		25,282,892,000
Less production during 1948*		2,002,448,000
Total proved reserves of crude oil as of Dec. 31, 1948		23,280,444,000
Increase in crude-oil reserves during 1948		1,792,759,000

b. NATURAL-GAS LIQUIDS—AGA AND API

(Barrels of 42 U.S. gal)

Total proved reserves of natural-gas liquids as of Dec. 31, 1947		3,253,975,000
Revisions of previous estimates and extensions of old pools	+ 405,874,000	
New reserves (new pools) discovered in 1948	64,683,000	
Proved reserves added in 1948		470,557,000
Total proved reserves as of Dec. 31, 1947 plus new proved reserves added in 1948		3,724,532,000
Less production during 1948*		183,749,000
Total proved reserves of natural-gas liquids as of Dec. 31, 1948		3,540,783,000
Increase in natural-gas liquids reserves during 1948		286,808,000

Table 2 (*Continued*)

c. Total Liquid Hydrocarbons—API and AGA

(Barrels of 42 U.S. gal)

Total proved reserves as of Dec. 31, 1947		24,741,660,000
Revisions of previous estimates and extensions of old pools	+ 3,804,600,000	
New reserves (new pools) discovered in 1948	461,164,000	
Proved reserves added in 1948		4,265,764,000
Total proved reserves as of Dec. 31, 1947 plus new proved reserves added in 1948		29,007,424,000
Less production during 1948*		2,186,197,000
Total proved reserves of liquid hydrocarbons as of Dec. 31, 1948		26,821,227,000
Increase in total liquid-hydrocarbon reserves during 1948		2,079,567,000

* The 1948 production figures were compiled by the committee and are based on 11 months' actual production with an estimate for December. Any variance between the actual production, as later reported, and the figures used herein will be compensated for through revision when the following years reserve report is compiled. These revisions have in the past been very small.

Proved reserves are both drilled and undrilled. The *proved drilled* reserves, in any pool, include the oil estimated to be recoverable by the production systems now in operation, whether primary or secondary, and from the area actually drilled up on the spacing pattern in vogue in that pool. The *proved undrilled* reserves, in any pool, include reserves under undrilled spacing units which are so close, and so related, to the drilled units that there is every reasonable probability that they will produce when drilled.

In the case of new discoveries, both of new fields and of new pools (pays, reservoirs) in old fields, which are seldom fully developed in the first year and in fact for several years thereafter, the estimates of proved reserves necessarily represent but a part of the reserves which may ultimately be assigned to the new reservoirs discovered each year. For a one-well field, where development has not yet gone beyond the discovery well, the area assigned as proved is usually small in regions of complex geological conditions but may be larger where the geology is relatively simple. In a sparsely drilled pool the area between wells is considered to be proved only if the geological and engineering data assure that such area will produce when drilled. The total of new oil through discoveries estimated as proved in any given year is generally comparatively small, because development is usually not extensive during the first year. The total of new oil through extensions, on the other hand, is comparatively large. As knowledge of the factors affecting production and reservoir performance becomes available, and as these factors are studied, reserves in older fields can be estimated with greater precision and revised accordingly. Therefore, the total quantity of the new proved reserves for the year includes the oil from discoveries and extensions and revisions of previous estimates.

The committee again wishes especially to stress the fact that its estimates of proved reserves cannot be used as a measure of the rate at which these reserves can be produced with or without physical waste. Oil cannot be produced from the permeable rocks in which it occurs at any desired rate, because the flow of oil through the pores of the oil-bearing rocks is definitely controlled by the physical factors of the reservoir. As a matter of fact, today's known oil can be recovered only over a period of many years and at gradually declining annual rates. This has been widely demonstrated by past performance under all kinds of operating conditions. Therefore, only incorrect conclusions as to the life of these reserves can be obtained by dividing these reserves by the current rate of production.

In Table 3 we show, in column (1), the crude-oil reserves as of Dec. 31, 1947. In column (2) are the changes in these crude-oil estimates due to extensions and revisions. In column (3) are the new reserves of crude oil discovered in 1948 in new fields and also in new pools (pays, reservoirs) in old fields. In column (4) are shown the committee's figures on production of crude oil (see footnote on production, Table 2), and in column (5) are shown the remaining reserves of crude oil as of Dec. 31, 1948. Column (6) shows the changes in crude-oil reserves during 1948.

In Table 4, in column (1), are shown the reserves of natural-gas liquids (condensate, natural gasoline, and liquefied petroleum gases —see complete definition in AGA report, p. 168) as of Dec. 31, 1947. In column (2) are the changes in these natural-gas liquids estimates due to extensions and revisions. In column (3) are the new reserves of natural-gas liquids discovered in 1948, in new fields and also in new pools (pays, reservoirs) in old fields. In column

(4) are shown the figures on production of natural-gas liquids, and in column (5) are shown the remaining reserves of natural-gas liquids as of Dec. 31, 1948. Column (6) shows the changes in natural-gas liquid reserves during 1948.

Table 5 is a consolidation of Tables 3 and 4 and shows the total liquid hydrocarbon reserves as of Dec. 31, 1947 and 1948, by states.

For comparative purposes we append a summary (Table 6) of the over-all figures contained in the committee's annual reports covering the period from 1937 to 1948. Figures for 1935 and 1936, which were first developed by the committee, are not available separately.

As in the past, this committee wishes to emphasize the fact that every effort has again been made to secure a fair, unprejudiced, and representative opinion. Each member in his district appointed a number of subcommittees to gather and study the necessary data. All previously determined factors pertaining to the various pools were examined and adjusted in the light of new information. The subcommittees, which were largely responsible for the data, were comprised of geologists and petroleum engineers with long experience in this class of work. We wish to acknowledge the valuable assistance of all those who have cooperated in this undertaking.

Attached hereto is a list of the members of the subcommittees.

THE COMMITTEE ON PETROLEUM RESERVES[11]

F. H. Lahee, Sun Oil Company, Dallas, Tex., Chairman

G. Clark Gester, Standard Oil Company of California, San Francisco, Calif., Vice-Chairman

Fred Van Covern, American Petroleum Institute, New York, N.Y., Secretary

R. F. Baker, The Texas Company, New York, N.Y.

L. T. Barrow, Humble Oil & Refining Company, Houston, Tex.

D. V. Carter, Magnolia Petroleum Company, Dallas, Tex.

Frank R. Clark, The Ohio Oil Company, Tulsa, Okla.

Alexander Deussen, Consulting Geologist, Houston, Tex.

J. M. Sands, Phillips Petroleum Company, Bartlesville, Okla.

P. R. Schultz, Stanolind Oil & Gas Co., Tulsa, Okla.

Theron Wasson, The Pure Oil Company, Chicago, Ill.

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[11] For members of API Committee on Petroleum Reserves Subcommittees see Appendix *B*, p. 409.

TABLE 3. ESTIMATED PROVED RESERVES OF CRUDE OIL IN THE UNITED STATES*
(Barrels of 42 U.S. gal)

State	Proved reserves as of Dec.31, 1947 (1)	Changes in proved reserves due to extensions (new oil) and revisions during 1948 (2)	Proved reserves discovered in new fields and in new pools in old fields in 1948† (3)	Production during 1948‡ (4)	Proved reserves as of Dec. 31, 1948 [Columns (1) + (2) + (3) − (4)] (5)	Changes in reserves during 1948 [Column (5) less Column (1)] (6)
Alabama	2,759,000	1,264,000	....	476,000	3,547,000	788,000
Arkansas	296,908,000	29,990,000	3,247,000	30,103,000	300,042,000	3,134,000
California	3,294,963,000	750,614,000	58,075,000	340,069,000	3,763,583,000	468,620,000
Colorado	381,882,000	255,000	350,000	17,029,000	365,458,000	(−) 16,424,000
Illinois	355,361,000	91,748,000	9,103,000	62,847,000	393,365,000	38,004,000
Indiana	46,015,000	5,892,000	5,129,000	7,957,000	49,079,000	3,064,000
Kansas	562,678,000	199,878,000	19,922,000	108,083,000	674,395,000	111,717,000
Kentucky	64,550,000	1,988,000	1,305,000	8,634,000	59,209,000	(−) 5,341,000
Louisana	1,791,004,000	201,728,000	51,361,000	174,803,000	1,869,290,000	78,286,000
Michigan	69,714,000	9,894,000	6,667,000	16,892,000	69,383,000	(−) 331,000
Mississippi	303,677,000	91,962,000	13,434,000	43,627,000	365,446,000	61,769,000
Montana	114,662,000	12,258,000	1,550,000	9,526,000	118,944,000	4,282,000
Nebraska	866,000	235,000	....	236,000	865,000	(−) 1,000
New Mexico	530,483,000	61,017,000	8,083,000	47,352,000	552,231,000	21,748,000
New York	71,519,000	....	....	4,403,000	67,116,000	(−) 4,403,000
Ohio	28,994,000	3,454,000	....	3,906,000	28,542,000	(−) 452,000

Oklahoma	952,990,000	412,886,000	39,746,000	155,221,000	1,250,401,000	297,411,000
Pennsylvania	122,720,000	....	....	12,914,000	109,806,000	(−) 12,914,000
Texas	11,777,537,000	1,450,188,000	155,804,000	899,311,000	12,484,218,000	706,681,000
West Virginia	36,092,000	3,200,000	100,000	2,695,000	36,697,000	605,000
Wyoming	679,311,000	70,656,000	21,780,000	55,960,000	715,787,000	36,476,000
Miscellaneous§	3,000,000	(−) 381,000	825,000	404,000	3,040,000	40,000
Total United States	21,487,685,000	3,398,726,000	396,481,000	2,002,448,000	23,280,444,000	1,792,759,000

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* API committee.

† Only a limited area is assigned to each new discovery, even though the committee may believe that eventually a much larger area will produce; for, in this report, the concern is only with actually proved reserves.

‡ See footnote, Table 2.

§ Includes Florida, Missouri, Tennessee, Utah, and Virginia.

Table 4. Estimated Proved Reserves of Natural-gas Liquids in the United States*

Includes Condensate, Natural Gasoline, and Liquefied Petroleum Gases

(Barrels of 42 U.S. gal)

State	Proved reserves as of Dec. 31, 1947 (1)	Changes in proved reserves due to extensions (new oil) and revisions during 1948 (2)	Proved reserves discovered in new fields and in new pools in old fields in 1948† (3)	Production during 1948‡ (4)	Proved reserves as of Dec. 31, 1948 [Columns (1) + (2) + (3) − (4)] (5)	Changes in reserves during 1948 [Column (5) less Column (1)] (6)
Alabama§						
Arkansas	58,259,000	3,220,000	249,000	4,271,000	57,457,000	(−) 802,000
California	312,151,000	20,088,000	2,149,000	26,480,000	307,908,000	(−) 4,243,000
Colorado	7,942,000	27,834,000	537,000	14,000	36,299,000	28,357,000
Illinois	17,920,000	10,152,000	....	3,910,000	24,162,000	6,242,000
Indiana	65,000	71,000	....	28,000	108,000	43,000
Kansas	88,812,000	15,621,000	17,000	2,106,000	102,344,000	13,532,000
Kentucky	15,344,000	410,000	206,000	1,559,000	14,401,000	(−) 943,000
Louisiana	462,814,000	67,206,000	16,113,000	22,037,000	524,096,000	61,282,000
Michigan	1,065,000	53,000	59,000	111,000	1,066,000	1,000
Mississippi	58,659,000	721,000	942,000	2,758,000	57,564,000	(−) 1,095,000
Montana	1,360,000	2,840,000	....	200,000	4,000,000	2,640,000
New Mexico	85,922,000	(−) 5,756,000	4,342,000	4,261,000	80,247,000	(−) 5,675,000

New York§		70,000	9,000	151,000	1,664,000	(−) 72,000
Ohio	1,736,000	53,685,000	8,225,000	16,525,000	200,388,000	45,385,000
Oklahoma	155,003,000	467,000	233,000	291,000	2,645,000	409,000
Pennsylvania	2,236,000	180,126,000	31,204,000	93,719,000	2,074,674,000	117,611,000
Texas	1,957,063,000	1,076,000	359,000	3,742,000	15,214,000	(−) 2,307,000
West Virginia	17,521,000	27,971,000	....	1,564,000	36,307,000	26,407,000
Wyoming	9,900,000	19,000	39,000	22,000	239,000	36,000
Miscellaneous‖	203,000					
Total United States	3,253,975,000	405,874,000	64,683,000	183,749,000	3,540,783,000	286,808,000

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* API and AGA committees.

† Only a limited area is assigned to each new discovery, even though the committee may believe that eventually a much larger area will produce; for, in this report, the concern is only with actually proved reserves.

‡ See footnote, Table 2.

§ Included in "Miscellaneous."

‖ Includes Alabama, Florida, New York, and Utah.

TABLE 5. ESTIMATED PROVED RESERVES OF LIQUID HYDROCARBONS IN THE UNITED STATES*
(Barrels of 42 U.S. gal)

State	Proved reserves as of Dec. 31, 1947 (1)	Changes in proved reserves due to extensions (new oil) and revisions during 1948 (2)	Proved reserves discovered in new fields and in new pools in old fields in 1948† (3)	Production during 1948‡ (4)	Proved reserves as of Dec. 31, 1948 [Columns (1) + (2) + (3) − (4)] (5)	Changes in reserves during 1948 [Column (5) less Column (1)] (6)
Alabama§	2,759,000	1,264,000	....	476,000	3,547,000	788,000
Arkansas	355,167,000	33,210,000	3,496,000	34,374,000	357,499,000	2,332,000
California	3,607,114,000	770,702,000	60,224,000	366,549,000	4,071,491,000	464,377,000
Colorado	389,824,000	28,089,000	887,000	17,043,000	401,757,000	11,933,000
Illinois	373,281,000	101,900,000	9,103,000	66,757,000	417,527,000	44,246,000
Indiana	46,080,000	5,963,000	5,129,000	7,985,000	49,187,000	3,107,000
Kansas	651,490,000	215,499,000	19,939,000	110,189,000	776,739,000	125,249,000
Kentucky	79,894,000	2,398,000	1,511,000	10,193,000	73,610,000	(−) 6,284,000
Louisiana	2,253,818,000	268,934,000	67,474,000	196,840,000	2,393,386,000	139,568,000
Michigan	70,779,000	9,947,000	6,726,000	17,003,000	70,449,000	(−) 330,000
Mississippi	362,336,000	92,683,000	14,376,000	46,385,000	423,010,000	60,674,000
Montana	116,022,000	15,098,000	1,550,000	9,726,000	122,944,000	6,922,000
Nebraska	866,000	235,000	....	236,000	865,000	(−) 1,000
New Mexico	616,405,000	55,261,000	12,425,000	51,613,000	632,478,000	16,073,000
New York§	71,519,000	....	....	4,403,000	67,116,000	(−) 4,403,000

Ohio	30,730,000	3,524,000	9,000	4,057,000	30,206,000	(−) 524,000
Oklahoma	1,107,993,000	466,571,000	47,971,000	171,746,000	1,450,789,000	342,796,000
Pennsylvania	124,956,000	467,000	233,000	13,205,000	112,451,000	(−) 12,505,000
Texas	13,734,600,000	1,630,314,000	187,008,000	993,030,000	14,558,892,000	824,292,000
West Virginia	53,613,000	4,276,000	459,000	6,437,000	51,911,000	(−) 1,702,000
Wyoming	689,211,000	98,627,000	21,780,000	57,524,000	752,094,000	62,883,000
Miscellaneous‖	3,203,000	(−) 362,000	864,000	426,000	3,279,000	76,000
Total United States	24,741,660,000	3,804,600,000	461,164,000	2,186,197,000	26,821,227,000	2,079,567,000

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* API and AGA committees.

† Only a limited area is assigned to each new discovery, even though the committee may believe that eventually a much larger area will produce; for, in this report, the concern is only with actually proved reserves.

‡ See footnote, Table 2.

§ Crude oil only; natural-gas liquids not separable from miscellaneous grouping in Table 4.

‖ Includes Alabama and New York natural-gas liquids; Missouri, Tennessee, and Virginia crude; Florida and Utah crude and natural-gas liquids.

Table 6. Summary of Committee's Annual Reports Covering Period 1937 to 1948
(Barrels of 42 U.S. gal)

Year	New oil found during year			Production during year* (4)	Estimated proved reserves as of end of year [Column (3) less Column (4)] (5)	Increase over previous year (6)
	Through revisions of previous estimates and extensions to known fields (1)	Through discoveries of new fiields and of new pools in old fields (2)	Total through new discoveries, extensions, and revisions [Columns (1) + (2)] (3)			
Proved reserves as reported prior to 1946						
1936	....	....	....	....	13,063,400,000	
1937	2,792,790,000	928,742,000	3,721,532,000	1,277,664,000	15,507,268,000	2,443,868,000
1938	2,243,571,000	810,493,000	3,054,064,000	1,213,186,000	17,348,146,000	1,840,878,000
1939	2,058,455,000	340,667,000	2,399,122,000	1,264,256,000	18,483,012,000	1,134,866,000
1940	1,607,012,000	286,338,000	1,893,350,000	1,351,847,000	19,024,515,000	541,503,000
1941	1,538,989,000	429,974,000	1,968,963,000	1,404,182,000	19,589,296,000	564,781,000
1942	1,618,925,000	260,051,000	1,878,976,000	1,385,479,000	20,082,793,000	493,497,000
1943	1,202,368,000	282,418,000	1,484,786,000	1,503,427,000	20,064,152,000	(−)18,641,000
1944	1,556,192,000	511,308,000	2,067,500,000	1,678,421,000	20,453,231,000	389,079,000
1945	1,690,315,000	419,984,000	2,110,299,000	1,736,717,000	20,826,813,000	373,582,000
Dec. 31, 1945 estimated proved reserves of crude oil only†					19,941,846,000	

Proved reserves as reported for 1946 and thereafter						
Crude oil only *						
1946	2,413,628,000	244,434,000	2,658,062,000	1,726,348,000	20,873,560,000	931,714,000
1947	2,019,140,000	445,430,000	2,464,570,000	1,850,445,000	21,487,685,000	614,125,000
1948	3,398,726,000	396,481,000	3,795,207,000	2,002,448,000	23,280,444,000	1,792,759,000
Natural-gas liquids only						
1946	(..............This detail not available for 1946................)				3,163,219,000	
1947	192,237,000	59,301,000	251,538,000	160,782,000	3,253,975,000	90,756,000
1948	405,874,000	64,683,000	470,557,000	183,749,000	3,540,783,000	286,808,000
Total liquid hydrocarbons						
1946	(..............This detail not available for 1946................)				24,036,779,000	
1947	2,211,377,000	504,731,000	2,716,108,000	2,011,227,000	24,741,660,000	704,881,000
1948	3,804,600,000	461,164,000	4,265,764,000	2,186,197,000	26,821,227,000	2,079,567,000

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* See footnote, Table 2.

† Up to an including its figures on proved reserves of petroleum, as of Dec. 31, 1945, the committee combined under that heading the estimated proved reserves cycle-plant and lease condensate. As of Dec. 31, 1945, the reserves so included totaled 884,967,000 bbl and as of Dec. 31, 1944, there were 668,701,000 bbl included. Beginning with the report of Dec. 31, 1946, the figures in this table show crude-oil and natural-gas liquids. It is to be remembered that, previous to Dec. 31, 1946, not all classes of natural-gas liquids were included. For this reason the totals for crude-oil and natural-gas liquids, as herewith recorded for 1946, 1947, and 1948, are not comparable with the figures recorded for years prior to 1946.

Part 3. ESTIMATE OF UNITED STATES NATURAL-GAS RESERVES

By The American Gas Association

The report of the Committee on Natural Gas Reserves of the AGA follows:

Your Committee on Natural Gas Reserves herewith submits its fourth annual report, summarizing the proved recoverable reserves of natural gas and natural-gas liquids of the United States, as of Dec. 31, 1948, as follows:

Natural-gas Reserves*

(Thousands of cubic feet)

Total proved reserves as of Dec. 31, 1947		165,926,914,000
Extensions and revisions of previous estimate	9,769,483,000	
New Reserves discovered in 1948	4,129,089,000	
Net changes in "stored gas" during 1948.	51,482,000	
Total proved reserves added and net changes in "stored gas" during 1948		13,950,054,000
Total proved reserves as of Dec. 31, 1947, and additions during 1948		179,876,968,000
Deduct production during 1948		6,007,628,000
Total proved reserves of natural gas as of Dec. 31, 1948		173,869,340,000

* Reserves data are shown by states in Table 7.

Natural-gas Liquids Reserves*

(Barrels of 42 U.S. gal)

Total proved reserves as of Dec. 31, 1947		3,253,975,000
Extensions and revisions of previous estimate	405,874,000	
New reserves discovered in 1948	64,683,000	
Total proved reserves added in 1948		470,557,000
Total proved reserves as of Dec. 31, 1947, and new proved reserves added in 1948		3,724,532,000
Deduct production during 1948		183,749,000
Total proved reserves of natural gas liquids as of Dec. 31, 1948		3,540,783,000

* Reserves data are shown by states in Table 8.

The committee has included in this report for the first time a study of the natural gas *located* in underground storage reservoirs. The "stored gas" is considered to be the gas which has been transferred from its original location in a gas and/or oil field to another natural underground reservoir for the primary purposes of conservation, fuller utilization of pipe-line capacities, and more effective delivery to markets. The stored-gas reserve is the quantity which has been placed in a natural reservoir and not yet removed. Any additional recoverable gas which may have been in the underground storage reservoirs when injection was begun, and has not yet been produced is classified in its proper category and listed as in the committee's earlier reports. The distinction is now made between "production" of gas from its original reservoir and "net change in underground storage."

Tables 9 and 10 are summaries of the committee's annual reports for the period from Dec. 31, 1945, to Dec. 31, 1948. Table 9 reflects the natural-gas reserve position of the United States at the end of each of the last four years. Table 10 shows the natural-gas liquid reserves of the United States for the last three years, since an estimate of natural-gas liquids was not included in the committee's first report.

In its report of Dec. 31, 1946, this committee defined natural-gas liquids as ". . . those hydrocarbon liquids that are gaseous in the reservoir but are obtainable by condensation or absorption. Natural gasoline, condensate, and liquefied petroleum gases fall in this category." In order to prevent misunderstanding of this term it is further amplified as follows: the natural-gas liquids are those heavier hydrocarbon components of the natural gas which are removed and reduced to the liquid state by various processes. These processes usually take place in the field separator, scrubber, gasoline plant, or cycling plant. The liquids so collected and the products made from them in some of the modern plants are known by a variety of names, but they have been grouped together here under the general heading "natural-gas liquids."

The committee emphasizes again that it is not possible to estimate the total reserves of a field in the year of discovery. Satisfactory estimates can be made only after sufficient development of the field and, in some cases, adequate production history. For these reasons, the reserves listed as discovered during any current year must be considered only as the reserves indicated by the drilling in that year. The estimated reserves of these new fields and

TABLE 7. ESTIMATED PROVED RECOVERABLE RESERVES OF NATURAL GAS IN THE UNITED STATES
(Millions of cubic feet—14.65 psia, at 60°F)

State	Reserves as of Dec. 31, 1947	Changes in reserves during 1948[1]				Reserves as of Dec. 31, 1948[1]				
		Extensions and revisions	Discoveries of new fields and new pools in old fields	Net change in underground storage[2]	Net Production[3]	Total	Nonassociated[4]	Associated[5]	Dissolved[6]	Underground storage[7]
Arkansas	890,149	73,969	3,484	(−) 10	65,754	901,838	457,906	161,919	280,568	1,445
California	10,164,356	498,673	111,257	(−)2,699	578,994	10,192,593	2,911,991	3,052,802	4,215,775	12,025
Colorado	331,866	621,577	408,148	....	12,412	1,349,179	586,757	40,939	721,483	
Illinois	221,131	43,310	....	....	36,637	227,804	7,967	20,000	199,837	
Indiana	13,000	14,104	....	....	5,504	21,600	6,000	....	15,600	
Kansas	14,556,916	124,304	2,385	1,213	276,986	14,407,832	13,959,636	210,292	211,035	26,869
Kentucky	1,379,480	69,775	9,000	7,896	88,000	1,378,151	1,295,122	....	73,000	10,029
Louisiana	23,481,233	532,638	722,859	....	759,210	23,977,520	18,909,691	3,490,004	1,577,825	
Michigan	168,469	14,490	11,705	10,461	22,138	182,987	121,502	....	45,876	15,609
Mississippi	2,452,760	54,413	52,423	....	55,260	2,504,336	1,743,948	464,632	295,756	
Montana	700,510	189,244	1,966	1,575	40,690	852,605	485,030	337,121	28,879	1,575
New Mexico	5,990,283	(−)214,670	108,930	989	279,171	5,606,361	2,824,102	1,991,862	786,557	3,840
New York	64,900	4,098	....	3,073	4,456	67,615	59,720	....	725	7,170
Ohio	611,200	57,780	7,880	13,325	60,732	629,453	542,608	....	38,500	48,345
Oklahoma	11,350,864	447,543	208,636	(−) 283	674,315	11,332,445	7,660,624	1,125,136	2,534,088	12,597

Pennsylvania....	483,063	182,967	12,000	13,972	74,592	617,410	530,721	....	45,750	40,939
Texas...........	90,025,566	6,563,060	1,830,349	....	2,710,422	95,708,553	68,663,367	16,725,023	10,320,163	
Utah............	66,670	....	10,000	....	6,872	69,798	69,798			
West Virginia....	1,780,735	123,462	37,000	1,970	206,000	1,737,167	1,622,235	....	89,500	25,432
Wyoming........	1,191,788	363,063	588,067	....	49,178	2,093,740	927,796	257,308	908,636	
Miscellaneous[8]...	1,975	5,683	3,000	....	305	10,353	7,993	....	2,360	
Total..........	165,926,914	9,769,483	4,129,089	51,482	6,007,628	173,869,340	123,394,514	27,877,038	22,391,913	205,875

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[1] Excludes shrinkage caused by natural-gas liquids recovery.

[2] The net difference between gas stored in and gas withdrawn from underground storage reservoirs.

[3] Net production equals gross withdrawals less gas injected into underground reservoirs; changes in underground storage are excluded.

[4] Nonassociated gas is free gas not in contact with crude oil in the reservoirs.

[5] Associated gas is free gas in contact with crude oil in the reservoirs.

[6] Dissolved gas is gas in solution with crude oil in the reservoirs.

[7] Gas held in underground reservoirs for storage purposes only.

[8] Includes Alabama, Florida, Missouri, Nebraska, and Virginia.

TABLE 8. ESTIMATED PROVED RECOVERABLE RESERVES OF NATURAL-GAS LIQUIDS* IN THE UNITED STATES
(Thousands of barrels)

State	Reserves as of Dec. 31, 1947	Changes in Reserves during 1948			Reserves as of Dec. 31, 1948			
		Extensions and revisions	Discoveries of new fields in old pools	Net production	Total	Nonassociated	Associated	Dissolved
Arkansas	58,259	3,220	249	4,271	57,457	36,468	7,926	13,063
California	312,151	20,088	2,149	26,480	307,908		103,259	204,649
Colorado	7,942	27,834	537	14	36,299	537		35,762
Illinois	17,920	10,152	......	3,910	24,162	40	100	24,022
Indiana	65	71	......	28	108	30		78
Kansas	88,812	15,621	17	2,106	102,344	97,695	2,539	2,110
Kentucky	15,344	410	206	1,559	14,401	14,401†		
Louisiana	462,814	67,206	16,113	22,037	524,096	382,319	95,908	45,869
Michigan	1,065	53	59	111	1,066	607		459
Mississippi	58,659	721	942	2,758	57,564	24,563	27,641	5,360
Montana	1,360	2,840	......	200	4,000		4,000	
New Mexico	85,922	(−)5,756	4,342	4,261	80,247	23,879	30,902	25,466
Ohio	1,736	70	9	151	1,664	1,664†		
Oklahoma	155,003	53,685	8,225	16,525	200,388	95,869	16,436	88,083
Pennsylvania	2,236	467	233	291	2,645	2,645†		
Texas	1,957,063	180,126	31,204	93,719	2,074,674	1,314,800	297,052	462,822
Utah	200	....	30	21	209	209		

West Virginia	17,521	1,076	359	3,742	15,214	15,214†		
Wyoming	9,900	27,971		1,564	36,307	12,191	....	24,116
Miscellaneous‡	3	19	9	1	30	24	....	6
Total	3,253,975	405,874	64,683	183,749	3,540,783	2,023,155	585,763	931,865

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* Includes condensate, natural gasoline, and liquefied petroleum gas.

† Not allocated by types, but occurring principally in column shown.

‡ Includes Alabama, Florida, Missouri, Nebraska, New York, and Virginia.

pools will be revised in future reports and shown as "extensions and revisions."

The procedures followed in arriving at and assembling the reserve figures were the same as those used in past reports. The proved reserves may be in either the drilled or the undrilled portion of a given field. Where the undrilled areas are considered proved, they are so related to the developed acreage and to the known field geology and structure that their productive ability is considered assured. Recoverable reserves of natural gas are the reserves

TABLE 9. SUMMARY OF ANNUAL ESTIMATES OF NATURAL-GAS RESERVES FOR PERIOD DEC. 31, 1945, TO DEC. 31, 1948

(Millions of cubic feet—14.65 psia, at 60°F)

Year	Natural gas added during year			Net change in storage	Net production during year	Estimated proved reserves as of end of year	Increase over previous year
	Extensions and revisions	Discoveries of new fields and new pools in old fields	Total of discoveries, revisions and extensions				
1945	....	....	....	......	....	147,789,367	
1946	.........*	.........*	17,729,152	......*	4,942,617	160,575,901	12,786,535
1947	7,570,654	3,410,170	10,980,824	......*	5,629,811	165,926,914	5,351,013
1948	9,769,483	4,129,089	13,898,572	51,482	6,007,628	173,869,340	7,942,426

* Not estimated.

TABLE 10. SUMMARY OF ANNUAL ESTIMATES OF NATURAL-GAS LIQUIDS RESERVES FOR PERIOD DEC. 31, 1946, TO DEC. 31, 1948

(Thousands of barrels of 42 U.S. gal)

Year	Natural-gas liquids added during year			Net production during year	Estimated proved reserves as of end of year	Increase over previous year
	Extensions and revisions	Discoveries of new fields and new pools in old fields	Total of discoveries, revisions and extensions			
1946	....	......	....	129,262	3,163,219	
1947	192,237	59,301	251,538	160,782	3,253,975	90,756
1948	405,874	64,683	470,557	183,749	3,540,783	286,808

estimated to be producible under present operating practices. Since the estimates are made by fields, the recovery factors or abandonment pressures used in the calculations were determined by the operating conditions of each individual field. Proved recoverable reserves of natural-gas liquids are those contained in recoverable gas reserves and extractable by methods now in use.

In the preparation of these estimates, as in those of previous years, this committee has had the helpful cooperation of the Committee on Petroleum Reserves of the API. To that group this committee is indebted in large measure for the estimates of the dissolved gas reserves, which are based on that committee's estimate of crude-oil reserves. Incorporated in this report are the results of careful study of many hundreds of fields and pools throughout the United States. Such an undertaking requires the help of specially trained geologists and engineers familiar with the various producing areas throughout the country. The committee is fortunate in having received the help of such a group of men, who have served as subcommitteemen. They have given generously of their time and efforts to the end that these estimates might be complete and as accurate as possible. This committee expresses its appreciation to these men.

COMMITTEE ON NATURAL GAS RESERVES[12]

N. C. McGowen, United Gas Corporation, Chairman
George H. Smith, American Gas Association, Secretary
O. E. Zwanzig, American Gas Association, Assistant Secretary

R. M. Bauer, Southern California Gas Company
E. A. Brown, Lone Star Gas Company
R. O. Garrett, Arkansas Louisiana Gas Company
Charles C. Hoffman, Cities Service Gas Company
Frederick S. Lott, Bureau of Mines, Department of the Interior
W. S. McCabe, Stanolind Oil and Gas Company
L. H. Meltzer, Union Producing Company
Perry Olcott, Humble Oil and Refining Company
E. E. Roth, Columbia Engineering Corporation
J. T. Scopes, Union Producing Company
Henry Toler, Southern Natural Gas Company
C. E. Turner, Phillips Petroleum Company

[12] For members of AGA Committee on National Gas Reserves subcommittees see Appendix *C*, p. 413.

Part 4. MORE OIL FOR AMERICA[13]

By L. F. McCollum

President, Continental Oil Company, and Chairman, Subcommittee on Long-term Availability, National Oil Policy Committee, American Petroleum Institute

You have been hearing a lot of loose talk lately to the effect that America is running out of oil. Such talk has been particularly widespread during the past year or so. Only last May it was said at a hearing in Washington that, and I quote, "The nation is in a grave situation with respect to its petroleum."

Those rumors naturally have disturbed the oil-consuming public. They also have led to a clamor in some quarters for government regulation or even for such drastic action as government ownership of the petroleum industry. Yet the fact is that these statements appear to be as preposterous as those dire predictions made repeatedly for almost a hundred years.

In 1922, for example, the U.S. Geological Survey reported that this country's proved reserves had been reduced to 9 billion barrels. In 1908, Director Day of the Survey declared that total reserves *and* resources couldn't amount to more than 24½ billion barrels. In 1874, just 15 years after the first oil well was drilled, Pennsylvania's State Geologist Wrigley estimated the United States had enough petroleum to keep its kerosene lamps burning for only 4 years.

The granddaddy of all the scare stories was published as an advertisement for Kier's "Rock Oil" several years *before* that first well was drilled. It warned prospective customers to "hurry, before this wonderful product is depleted from Nature's laboratory!"

So much for rumors. Now let's look at the facts!

To start with, I want to point out that, to date, the United States has produced more than 35 billion barrels of crude oil. To put it another way, our country has produced 65 per cent of all the world's petroleum. Yet, despite the tremendous amounts of oil taken out of the ground to meet the soaring needs of United States citizens, this country's proved crude reserves stand at the record high of approximately 21½ billion barrels. (That estimate does not take into consideration, of course, additional vast quantities of natural-gas liquids.)

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[13] Address before Annual Meeting, API, Nov. 11, 1948.

Next, I want to quote from a detailed Report on Long-term Petroleum Availability (see p. 185 for full report). This report was prepared, after months of careful study, by an API committee of which I am proud to be chairman. It says in part:

"Petroleum liquids from natural sources will be available within the United States in substantially increased amounts. Under favorable conditions, there will be increasing amounts of petroleum readily available from other areas in both the Western and Eastern Hemispheres for importation into the United States if needed. There are abundant sources of raw materials within the United States from which petroleum products can be produced synthetically to supply all needs if it becomes necessary or advisable to produce them by this method. In short, this nation can continue to grow through the use of petroleum products as a major source of energy."

That is certainly a cheerful prospect. It should set at rest any fears which may have been aroused as to our oil supply. But, by implication, it raises an interesting and fundamental question, namely, how has it happened that none of the direful predictions which I quoted have materialized?

There are two basic answers: In the first place, the viewers-with-alarm were thinking in static terms. They did not take adequately into account the possibilities of large oil discoveries; neither did they give weight to a dynamic technology.

Kier worked on the assumption that he would have to keep on skimming his "Rock Oil" off the surfaces of polluted salt wells. Dr. Wrigley believed oil could be found only along the creek beds of Pennsylvania. Dr. Day did not dream of the fabulously rich East Texas field discovered in 1930.

The second reason why those predictions went wrong was because they made no allowance for the underlying basic drive of America's system of free competitive enterprise. The men who made those forecasts did not stop to realize that United States oil producers, operating under a profit system unfettered by government interference, could perform miracles. They ignored the economic truism that those who work hard to forward their own best interests necessarily work also for the good of all the people.

Just think for a moment of the long, long way our industry has come since 1859, when Colonel Drake used a donkey engine and an improvised string of cable tools to strike oil at 69½ ft.

Intrepid explorers now calmly accept the fact that only one out of five wildcat wells strikes oil. They range all over America and deep into the deserts, mountains, and jungles of other continents to find enormous reserves. They use the latest developments in geology, geophysics, electronics, seismology, and other sciences to carry out their search.

Oil men know that the only way to find petroleum is to drill for it. Over the years they have brought in more than 860,000 producing oil wells. They have developed rotary-drilling methods which can penetrate below 17,000 ft. They have developed a technique of directional drilling to tap reserves under rivers, hills, and swamps. They have plumbed lakes and ocean depths.

They have not wasted the nation's resources in their efforts to keep Americans supplied with fuel. Instead they have developed conservation practices such as the proper spacing of wells, the careful regulation of their flow, and their repressuring with water or gas. Such practices have kept half the oil wells ever drilled in continuous production to this day. They also have made possible the recovery of billions of barrels of crude, which, a short 20 years ago, were thought to be forever locked in the ground.

Continuing improvements in refining, such as thermal and catalytic cracking, have made more and better products available to the public. Unceasing research has found new uses for such products. Those advances have not merely added to our natural resources—they have actually multiplied them. By that I mean that, as a direct result of the spirit of enterprise which has always dominated the petroleum industry, people are getting more and more work out of each barrel of oil. This is so because higher quality fuels and better lubricants are being used to operate engines and other equipment having greater efficiency and longer life. A complicated system of pipe lines, tankers, barges, tank cars, and trucks has been built at untold expense to carry oil products to a quarter of a million service stations and other marketing outlets.

All of this, let me remind you, is being done with American know-how by progressive oilmen working under the incentive of a reasonable profit. They do the job on their own initiative with private capital, governed by the laws of supply and demand.

What has been the result?

Because of the abundant oil supply, American workmen are able to utilize more "horsepower" on their jobs than the workers of any other land. It is estimated that every employee in our manufacturing industries has about 6 mechanical horsepower at his command. Since a worker, plus a "horsepower," can outwork a hundred manual laborers, the productivity of United States industry is prodigious. Naturally, therefore, America's standard of living is the highest on earth. To look at it from a different viewpoint, the prosperity which Americans enjoy can be traced largely to the fact that they use, in two weeks, as much oil as the people of the rest of the world consume in an entire year.

It must be understood, of course, that the ingenuity of men in other industries has been constantly at work to stretch the usefulness of oil products and thereby further improve our living standards. The introduction of petroleum lubricants in the eighteen sixties was followed immediately by the invention of high-speed machinery. Since then the development of the automobile, airplane, chemical, railway, electrical, and other industries has gone hand in hand with the expansion of the petroleum business. When more efficient engines are needed, others develop them but oil provides the special fuels and lubricants required. When synthetic rubber had to be made during the Second World War, petroleum companies came forward with its basic raw materials—materials which are being compounded into "cold rubber" to make peacetime tires giving greater mileage than ever before. These are other examples of the working of a dynamic technology in a climate of free enterprise.

So it goes, in practically every field of endeavor. Worried men add up columns of cold figures and come to the conclusion that our oil supply can't possibly last. Other men with imagination, foresight, and indomitable will power go quietly about their jobs of supplying that oil and expanding its usefulness.

Oilmen provided most of the power needed to win two world wars. Right now they are supplying America with almost half of its energy.

Those energy requirements have more than doubled since 1915. Petroleum and natural gas have supplied 76 per cent of that increase. The industry accomplished this feat by turning out 48 per cent more oil in 1948 than in 1941, before the war, and 21 per cent more than in 1945, at the peak of the fighting.

Oilmen also are typically American in that they look toward the future with confidence. They believe they can supply even more fuel in the years ahead and thus still further enhance our living standards. They intend to continue to guarantee America's precious Fifth Freedom—the freedom of movement provided by our millions of oil-powered automobiles, diesel trains, buses, ships, and airplanes.

In order to explain this confidence which oilmen feel in America's future, let me turn now to a brief analysis of the Long-term Availability Report. This is the first time in history that such a report has been published. It was a difficult job. I want to pay tribute to the hard work put in by my fellow committeemen in bringing together and evaluating the best available data on the subject.

Committeemen went about the task thoroughly and painstakingly. More than 75 individuals participated. Each group called upon those geologists and production technicians who had intimate knowledge of the area under study. The result was that several hundred trained personnel assisted the committee and its various working groups.

I also want to stress that this report is not the "last word" on petroleum availability. There never will be a "last word" on that subject. Throughout the years, oilmen continually have had to raise their sights as new discoveries and improved techniques made previous estimates conservative.

To make this report the committee experts had to "freeze" oil technology and oil thinking as of the present moment. But technology and thought refuse to be frozen. Under our system of competitive initiative they plunge ahead at an ever-accelerating rate. That is the nature of progress. It is not unlikely that this report, too, will be found conservative when we meet here years hence.

Let me put it this way: Men burned wood for at least 50,000 years before they discovered coal. But 600 years after they discovered coal, they were using oil. And 80 years after that, they hit upon atomic fission.

Within the last 150 years, the human race has made more material progress than in all the millenniums of its previous life on this planet. And I might add that the oil industry, as we know it today, really dates from the turn of this century. Under such circumstances you can see that all estimates of future happenings must be subject to almost constant change—must be hedged about with conditions.

Before I summarize the report—I urge all of you to read the report itself very carefully—let me speak for a moment about some of the premises on which it was based.

The committee assumed that there will be favorable economic conditions; that adequate materials will be available to carry on the industry's contemplated operations; that there will be no serious interruptions in the industry's activities in the event of war; and that *there will be no government regulation of, or restrictions upon, the industry's normal activities.*

Really, it is the last premise which is all-important. If the dead hand of government should descend upon us, for any reason, we would find our production retarded and it would be the beginning of the end of the oil industry as we know it. Under such circumstances, nobody knows exactly what would happen.

Let me cite just two examples of what *might* happen if the government should step in to control or operate the 34,000 competitive oil companies in this country. We all know that an adequate price for petroleum stimulates new discoveries, thus making more oil available. If the price goes too high, we overdiscover, there is a surplus of products, and the price is forced down. If the price falls too low, we underdiscover, demand exceeds supply, and the price rises again until a balance is created.

We also know that adequate profits largely supply the financing for additional development. So adequate prices and profits guarantee a continuing supply of products to consumers.

Now, if those two controlling factors were drastically interfered with or eliminated by government bureaucrats, the law of supply and demand would be thrown completely out of balance. We would have to assume that, as a result, supplies would dwindle and costs would soar, as has happened in all nations under government control today.

Another basic condition of the report is that it allows for a margin of error. This margin increases progressively as estimates are pushed further and further into the future. For this reason it was felt by the committee to be both necessary and desirable to show a probable upper and lower range within which future availability might be expected to fall. With this in mind, and subject to today's conditions and information, the committee believes that this study represents a reasonably reliable guide as to the probable availability of petroleum for consumption in the United States.

Now for some of the specific findings set forth:

By 1953, the availability of natural petroleum produced in the United States is estimated to reach an upper range of 7.3 million barrels a day. That figure would be 2.3 million barrels a day more than actual production in the peak war year of 1945. And, related to our population, the availability for all of 1953 would be equal to almost 800 gal for each person—about 80 per cent higher than what it was in 1941.

It is still impossible to foresee definitely the probable trends beyond 1953. From the best data now obtainable, no significant decline from that year's estimated rates is anticipated during the following five years. However, if a moderate decline in domestic output should be indicated later on, supplementary sources of petroleum and its products are expected to become available in larger volumes if and when needed.

One of those supplementary sources is made up of our large reserves of natural gas, oil shale, and coal, which can be synthesized into liquid fuels. The estimated availability of petroleum products from synthetic processes is relatively small during the next five years. On the other hand, technically feasible processes for the conversion of natural gas, oil shale, and coal to oil products have been developed. Future availability from those sources may be considered to be limited primarily by the practical considerations of the need for such production and the time, materials, and capital required to construct necessary facilities.

The proved natural-gas reserves of this country were estimated at 166 trillion cubic feet at the beginning of 1948. In terms of liquid petroleum this gas is almost equal to our proved oil reserves today. The oil-shale reserves are known to be in excess of the equivalent of 100 billion barrels of petroleum. The coal reserves are so great that any estimate of potential synthetics from this source would be too large to be of real significance. There is certainly enough coal underground to supply the oil requirements of this country for many generations to come.

There are other sources of oil available to be used if needed, while synthetics production is getting under way. Production of foreign petroleum is estimated to increase substantially during the five years 1949 to 1953. Total estimated production of crude petroleum in the foreign nations of the Western Hemisphere is expected to increase from 1¾ million barrels daily in 1948 to almost 2½ million barrels in 1953. In the Eastern Hemisphere (exclusive of Russia) production will jump from 1½ million barrels daily in 1948 to more than 2½ million barrels in 1953. Production in foreign countries is estimated to increase still further during the second five-year period.

It is beyond the scope of the committee's work to analyze future distribution of this foreign oil between consuming areas of the world. It can be assumed, though, that such production should increase the total amount available for consumption in the United States. Consumption within the principal foreign oil-producing countries is relatively small. At present the largest part of their output is available for use in other areas.

The committee report next turns its attention to the availability of natural gas and its relation to petroleum liquids. The ratio of proved reserves to production of this fuel stands at 30:1. With this high ratio and with the probability that reserves will continue to increase for the next few years as they have in the past, it is estimated that larger quantities of gas will become available to supplement liquid petroleum products in supplying the nation's energy requirements.

These are, in brief, the findings of the committee. They show:

1. That, on the basis of what we know today, petroleum liquids produced in this country will be available in substantially increased amounts as the years pass.
2. That those liquids will be supplemented, if need arises, by increased quantities of imported oil, of natural gas, and of synthetic fuels.

I am convinced, however, that the implications of this report go far beyond those two points.

They show, in the first place, that fears expressed in some quarters that America is rapidly running out of oil are groundless. They prove to the consuming public that the progressive petroleum industry is serving their best interests as it has always done in the past.

They point up the tremendous service which oil is rendering to the American public.

The present report also underlines by inference the fact that technology is the great multiplier; technology compounds man's ingenuity and his ability to better himself.

Let me put it this way: About the time of the First World War, petroleum engineers came into the industry, and companies began establishing research laboratories. As a result, oilmen learned more regarding the science of production and refining than they had in all the years since the Drake well was drilled. Those advances improved operating efficiency and reduced operating costs, with the result that petroleum prices today are still near the bottom of the commodity index of the U.S. Bureau of Labor Statistics.

That brings me to the last point I want to make. For the petroleum industry to expand and to meet America's future oil requirements, it must continue to be free from domination by demagogues who agitate for a rigidly controlled economy—an economy similar to those which are retarding the development of so many potentially rich foreign lands. The report itself warns that all bets are off if the government steps in—that those estimates of increased availability may have to be revised downward if such a thing happens.

We must take that warning to heart. The great truth which has been demonstrated by the performance of the petroleum industry of the United States is that progress and increasing usefulness are results of competitive efforts. Our achievement of the past in providing more and ever more oil for America is our most convincing evidence that, so long as our form of economy is unimpaired, we will continue to do the job which only an industry free of restraint can do.

We must fight both to retain our freedom of enterprise and to protect the living standards of the American people. We must convince our friends, our neighbors, our employees, our stockholders, and our customers that they would be enslaved by a regimented economy. We must hammer home, through every medium available to us, that the progressive petroleum industry as it stands today, alone can provide more oil for America.

Part 5. LONG-TERM AVAILABILITY OF PETROLEUM

Report by THE SUBCOMMITTEE ON LONG-TERM AVAILABILITY, NATIONAL OIL POLICY COMMITTEE, AMERICAN PETROLEUM INSTITUTE, *November*, 1948

INTRODUCTION

This report covers the results of a study of the amount of petroleum which can be expected to be available to this country for all purposes during the five-year period 1949 to 1953 and a statement covering the supply during the years 1954 to 1959.

The study shows that petroleum liquids from natural sources will be available within the United States in substantially increasing amounts; that under favorable conditions there will be increasing amounts of petroleum readily available from other areas in both the Western and Eastern Hemispheres for importation into the United States if needed; and that there are abundant sources of raw materials within the United States from which petroleum products can be produced synthetically to supply all needs if it becomes necessary or advisable to produce them by this method. In short, this nation can continue to grow through the use of petroleum products as a major source of energy.

The Study. The study is the most comprehensive undertaken by the oil industry in recent years. It was thorough and painstaking. More than 75 individuals were members of the subcommittee and its various working groups. Each group called upon those geologists and production technicians who had intimate knowledge of the area under study, with the result that several hundred trained personnel participated. Through these individuals and under the procedure followed, it was possible to obtain and consolidate a large portion of the industry's information on this subject.

In estimating future availability of oil for consumption in the United States, both the importance of the subject as well as the inherent difficulties of the undertaking have been recognized. Petroleum, being a natural resource contained in subsurface formations, must be discovered and developed before it can be produced and converted into the many oil products used by the consumer.

The discovery of new underground reserves and the development of these newly discovered fields is the industry's major operation, carried on continuously. It is the most important single factor affecting the estimates of future petroleum availability. The estimates are based on the industry's ever-increasing store of knowledge as to the prospects for further discovery and development, but, in the final analysis, the volume of newly discovered and developed oil cannot be determined accurately until the actual results of future drilling become available. It was felt, therefore, that it was both necessary and desirable to show a probable range within which future availability might be expected to fall. With this in mind and subject to the conditions set out in this report, it is believed that this study represents a reasonably reliable guide as to the probable availability of petroleum for consumption in the United States.

Petroleum products for consumption in the United States may be obtained from three principal sources, (1) domestically produced crude petroleum and natural-gas liquids; (2) synthetic production from natural gas, oil shale, and coal; and (3) petroleum produced in foreign countries in both the Western and Eastern Hemispheres. All three sources have been considered in this survey, with detailed estimates being shown for the five years 1949 to 1953. For the following five-year period 1954 to 1958, a more general analysis of probable availability has been made.

Basic Conditions. The results of the study should be considered in the light of the following basic conditions prevailing: That there will be favorable economic conditions; that there will be no government regulation of, or restrictions upon, the industry's normal activities; that adequate materials will be available to carry on the industry's contemplated operations; that estimated availability will be based on maximum efficient rates of production under engineering principles consonant with good conservation practices; and that there will be no serious interruptions in the industry's activities in the event of war. Any substantial deviation from these conditions in actual developments during the 10-year period, due to matters outside the control of the industry, necessarily would require modification of the forecasted availabilities.

Conclusions. 1. It is estimated that total availability of petroleum and petroleum products for consumption in the United States will increase substantially during the 10 years 1949 to 1958.

2. During the five years 1949 to 1953, the availability of natural liquid hydrocarbons (crude petroleum and natural-gas liquids) produced in the United States is estimated to increase as shown in the following tabulation:

Year	Probable range		Average, bbl daily
	Lower, bbl daily	Upper, bbl daily	
1949	6,120,000	6,300,000	6,210,000
1950	6,310,000	6,630,000	6,470,000
1951	6,460,000	6,920,000	6,690,000
1952	6,560,000	7,140,000	6,850,000
1953	6,600,000	7,320,000	6,960,000

For comparison, the actual domestic production of these liquids in 1948 is expected to approximate 5,900,000 bbl per day (5,500,000 bbl daily of crude petroleum and 400,000 bbl daily of natural-gas liquids). The estimated 1953 rates, therefore, would be equivalent to an increase over 1948 of 1,060,000 bbl daily on the basis of the average estimate of availability.

3. Supplementing the natural petroleum liquids produced in the United States during the next five years the estimated availability of petroleum products from synthetic processes, under foreseeable economic conditions, is relatively small, with the volume reaching approximately 30,000 bbl daily of oil products converted from natural gas by 1953. However, technically feasible and operable processes for the conversion of natural gas, oil shale, and coal to oil products have been developed, and large sources of supply of those raw materials exist.

4. Production of foreign petroleum is estimated to increase substantially during the five years 1949 to 1953. Total estimated production of crude petroleum in the foreign nations of the Western Hemisphere (for use in those foreign nations and for export) is estimated to increase from 1,750,000 bbl daily in 1948 to 2,490,000 bbl per day in 1953, and in the Eastern Hemisphere (exclusive of

Russia) from 1,500,000 bbl daily in 1948 to 2,520,000 bbl per day in 1953. Although it was beyond the scope of the study to estimate future distribution of this foreign oil between consuming areas of the world, these increases in total foreign production should increase the availability from these sources for consumption in the United States. In this connection, it is important to note that consumption within the principal foreign oil-producing countries is relatively small, and the largest part of the output of those countries is available for use in other areas.

5. For the second five-year period 1954 to 1958, adequate information on which to base detailed estimates of availability of natural liquid hydrocarbons produced in the United States will not be available for several years. From the best data now obtainable, no significant decline from the 1953 estimated rates is anticipated during the following five years, but it is impossible to to foresee definitely at this time the probable trends. However, as these trends become defined, and if a moderate decline in domestic output of natural liquid hydrocarbons should be indicated, supplementary sources of petroleum and its products are estimated to become available in larger volumes if needed. Large reserves of the raw materials for the synthetic production of oil exist in the form of natural gas, oil shale, and coal. Future availability from these sources may be considered to be limited primarily by the practical considerations of the need for such production and the time, materials, and capital required to construct necessary facilities. Under the conditions set forth in the report, the availability of petroleum produced in foreign countries in both the Western and Eastern Hemispheres is estimated to increase further during the second five-year period and provide additional supplementary supplies for consumption in the United States if needed.

6. Proved reserves of natural gas are at a relatively high ratio to consumption, and as distribution facilities are expanded, it is estimated that larger quantities of this fuel will be available to supplement liquid petroleum products in supplying the nation's energy requirements.

Estimated Availability of Crude Petroleum and Natural-gas Liquids Produced in the United States. In estimating the availability of crude petroleum and natural-gas liquids produced in the United States, it was both necessary and desirable to consider a probable range within which this availability may reasonably be expected to fall. Future availability can be measured only the degree of accuracy that it is possible to measure the results of future operations in the search for, and development of, additional underground sources of supply. Within a limited future period, these results can be approximated. As the period is extended, the margin of error unavoidably increases owing to a lack of the information that will later become available so as to permit a significant determination of the volume of oil found and developed. The following tabulations, therefore, show the estimates of future petroleum availability with an upper and lower range. The lower range may be considered as the minimum volume estimated to become available. The upper range represents the probable availability with more favorable results from exploratory and development activities, including unhampered leasing and development of the Continental Shelf. For comparison, figures are included for actual production (not availability) during the preceding 10 years, 1939 to 1948.

DOMESTIC CRUDE PETROLEUM
(Thousands of barrels daily)

Actual production*		Estimated availability			
Year	Amount	Year	Average	Probable range from average	
				Lower	Upper
1939	3,466				
1940	3,697				
1941	3,842				
1942	3,799				
1943	4,125				
1944	4,584	1949	5,760	5,670	5,850
1945	4,695	1950	5,995	5,840	6,150
1946	4,751	1951	6,190	5,970	6,410
1947	5,085	1952	6,330	6,050	6,610
1948†	5,500	1953	6,425	6,080	6,770

* According to U.S. Bureau of Mines.
† Partly estimated.

In addition to the foregoing figures covering crude petroleum, supplies of petroleum products are derived from natural-gas liquids. The actual production of these liquids and the estimated future availability are shown in the following tabulation:

DOMESTIC NATURAL-GAS LIQUIDS
(Thousands of barrels daily)

Actual production*		Estimated availability			
Year	Amount	Year	Average	Probable range from average	
				Lower	Upper
1939	141†				
1940	153†				
1941	222				
1942	228				
1943	240				
1944	273	1949	450	450	450
1945	307	1950	475	470	480
1946	316	1951	500	490	510
1947	362	1952	520	510	530
1948‡	400	1953	535	520	550

* According to U.S. Bureau of Mines.
† Does not include some cycle condensate included in subsequent years.
‡ Partly estimated.

Combining the figures for crude petroleum and for natural-gas liquids gives the total volume of natural liquid hydrocarbons produced in the United States as shown hereinafter:

TOTAL DOMESTIC CRUDE PETROLEUM AND NATURAL-GAS LIQUIDS
(Thousands of barrels daily)

Actual production*		Estimated Availability			
Year	Amount	Year	Average	Probable range from average	
				Lower	Upper
1939	3,607				
1940	3,850				
1941	4,064				
1942	4,027				
1943	4,365				
1944	4,857	1949	6,210	6,120	6,300
1945	5,002	1950	6,470	6,310	6,630
1946	5,067	1951	6,690	6,460	6,920
1947	5,447	1952	6,850	6,560	7,140
1948†	5,900	1953	6,960	6,600	7,320

* According to U.S. Bureau of Mines.
† Partly estimated.

As shown in the foregoing tabulations, the availability of liquid hydrocarbons (crude petroleum and natural-gas liquids) produced in the United States is estimated to increase during the five-year period 1949 to 1953. As compared with the 1948 production of crude petroleum and natural-gas liquids of 5,900,000 bbl daily, the average of the upper and lower range of estimated availability equals 6,960,000 bbl per day in 1953, an increase of 1,060,000 bbl daily over the 1948 production. The probable range in availability from this average figure of 6,960,000 bbl daily varies from a minimum of 6,600,000 bbl per day in 1953 to an upper figure of 7,320,000 bbl daily for that year. The lower range represents an increase of 700,000 bbl daily during the five years over 1948 production, whereas the upper range is equivalent to a 1,420,000-bbl per-day increase over the 1948 output.

For the following five-year period 1954 to 1958, a lack of adequate information makes it impossible to present detailed estimates. Whether availability from natural sources within this country will be subject to a moderate decline, a maintenance of then existing levels, or a continuing increase after 1953 are questions that cannot be resolved at this time. In this connection, however, the study does not indicate any sharp or substantial decline in the availability of domestically produced crude petroleum and natural-gas liquids during the second five-year period. Also, in this connection, the availability of petroleum from alternative or supplementary sources of supply, as set out in following sections of this report, must be considered.

Synthetic Petroleum Liquids. For a very long time the oil industry has been looking to synthetic fuels as one means of augmenting the petroleum supply of this country. It is estimated that private industry has already spent in excess of 100 million dollars in the development of synthetic processes. The industry is continuing to spend funds at a rate in excess of 10 million dollars a year, and as increased needs for synthetics should be manifested, far larger amounts would be applied to this field.

Already, processes for the conversion of natural gas, coal, and oil shale to oil products have been developed which are technically feasible and operable. A commercial plant is now under construction to convert natural gas to oil. At the present state of the art, refined products from coal and from oil shale are somewhat more costly than for natural petroleum, but it is possible that continued research and development work over the next decade will lead to processes for producing such products from one or both of these materials as cheaply as from natural petroleum.

The proved gas reserves of the country were estimated at 166 trillion cubic feet at the beginning of this year, whereas production in 1947 was at a rate of only 5.6 trillion cubic feet per year, or a ratio of reserves to production of almost 30:1. With this high ratio and with the probability that the reserves will continue to increase for the next few years as they have in the past, it seems reasonable that an increasing volume of gas could be dedicated to the synthetics industry without interfering with other demands for natural gas. The oil-shale reserves are known to be in excess of the equivalent of 100 billion barrels of petroleum. The coal reserves are so great that any estimate of potential synthetics from this source would be too large to be of real significance. There would certainly be adequate coal to supply the oil requirements of this country for many generations to come.

Based on the present plans of the industry and on the basis of present economic conditions, it is estimated that availability from synthetic production during the five years 1949 to 1953 will increase to approximately 30,000 bbl per day by the end of the period. This estimated production will be entirely from conversion of natural gas to oil. During the following five-year period 1954 to 1958, it is expected that synthetic production of petroleum products from natural gas will increase at an accelerated rate if needed, supplemented by a relatively small output from plants for the conversion of both oil shale and coal to oil.

In considering the foregoing outlook for synthetics, there is obviously a wide latitude for judgment because of the many conditions that might arise to change the conclusions significantly. Changes in the basic conditions, as set forth previously in this report, would have particularly important effects upon developments in the synthetic field. An additional factor bearing on this situation is the possibility of discovery of unexpectedly large new oil reserves.

Foreign Petroleum. Petroleum produced in foreign countries in both the Western and Eastern Hemispheres provides an additional source of supply for the United States, as a substantial portion of this foreign production has been developed and is being produced by American companies or their affiliates.

The following tabulation shows the total production of crude petroleum in foreign areas (excluding Russia) for the 10-year period 1939 to 1948 and the estimated production for the five years 1949 to 1953:

FOREIGN CRUDE PETROLEUM
(Thousands of barrels daily)

Year	Western Hemisphere	Eastern Hemisphere (exclusive of Russia)	Total foreign (exclusive of Russia)
		Actual production	
1939	914	713	1,627
1940	877	666	1,543
1941	989	584	1,573
1942	727	568	1,295
1943	823	673	1,496
1944	1,067	662	1,729
1945	1,256	719	1,975
1946	1,434	887	2,321
1947	1,592	1,061	2,653
1948*	1,750	1,500	3,250
		Estimated production	
1949	1,900	1,680	3,580
1950	2,060	1,840	3,900
1951	2,250	2,080	4,330
1952	2,450	2,260	4,710
1953	2,490	2,520	5,010

* Mid-year estimate.

The foregoing figures do not include a relatively small volume of allied liquid hydrocarbons and synthetic production amounting to approximately 50,000 bbl daily in 1948, which is estimated to increase to about 70,000 bbl per day in 1953, approximately one-fourth of which is from the foreign Western Hemisphere and three-fourths from Eastern Hemisphere sources.

With regard to these figures on foreign production, it should be noted that they are total quantities for use in foreign countries as well as supplying the import requirements of the United States. World distribution of these supplies involves questions of estimated oil demands and political considerations beyond the scope of this study. However, certain observations may be made with relation to the availability of this foreign production for consumption in the United States.

Petroleum produced in foreign countries of the Western Hemisphere has been and is being (1) consumed in the foreign nations of the Western Hemisphere, (2) exported for consumption in the United States, and (3) exported to Eastern Hemisphere countries to meet that hemisphere's deficiency in oil supply. Petroleum produced in the United States is also being supplied to meet a portion of the deficiency in Eastern Hemisphere output. An increased availability of foreign production for consumption in the United States may be expected as a result of increased Eastern Hemisphere production, making that area no longer dependent upon Western Hemisphere sources. To the extent that this may occur, it will obviously increase the availability of Western Hemisphere oil for use in the United States and other Western Hemisphere nations. In this connection it will be noted that the estimated production in the Eastern Hemisphere (excluding Russia) increases from 1,500,000 bbl daily in mid-1948 to 2,520,000 bbl per day in 1953, a rise of approximately 70 per cent in the five-year period. Foreign Western Hemisphere production is estimated to increase by about 40 per cent during this same period, from 1,750,000 bbl daily in 1948 to 2,490,000 bbl per day in 1953. Oil consumption in the principal foreign oil-producing countries is relatively small, with the largest part of the output in these countries being available for export.

For the second five-year period 1954 to 1959, foreign production is expected to continue to increase. In view of the large volume of proved reserves, production from Eastern Hemisphere sources may be expected to continue to increase at a faster rate than in the foreign Western Hemisphere.

Natural Gas. In view of the assignment to study the supply of petroleum liquids, no estimates of the availability of natural gas have been prepared other than a consideration of that portion of the gas for conversion into liquid products. However, the relationship of natural gas to petroleum liquids is an important factor in the over-all availability of fuels to supply the nation's energy requirements.

The three principal sources of energy in the United States are coal, oil, and natural gas—with water power playing a lesser role. For many uses, these three fuels are directly competitive.

As previously stated, the proved reserves of natural gas have increased steadily, and were estimated at approximately 166 trillion cubic feet at the beginning of the year 1948. These proved reserves are at the relatively high ratio of approximately 30:1 to present consumption, and there is no question that availability of this fuel at the producing wells considerably exceeds present distribution facilities. As distribution facilities are expanded, a larger and larger volume of natural gas will be made available to supply over-all fuel needs in this country. To this degree, therefore, natural gas is closely related to the availability of liquid petroleum, and it represents a highly important supplementary source of fuel energy.

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Part 6. HOW THE OIL-SUPPLY PROBLEM WAS LICKED[14]

By Robert E. Wilson

Chairman of the Board, Standard Oil Company (Indiana)

Just how has the superdemand for oil products been met, in spite of shortages of needed steel, man power, and money, and in spite of inadequate transportation facilities?

The answer, I believe, lies in three C's—Cooperation, Conservation, and Competition. Let us consider each briefly.

Before we pat ourselves on the back too enthusiastically, we must recognize that the petroleum industry has had fine cooperation from the public, from Federal, state, and municipal officials, from the railroads, from the steel industry, from the manufacturers of oil burners, and from others. . . . A few examples will represent the many that might be cited.

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[14] The problem of meeting the great postwar increase on demand for petroleum products became most acute during the winter of 1947–1948. This is an excerpt from an address given before the American Petroleum Institute, Nov. 10, 1948.—Editor.

In an analysis made late in the spring of 1948 a representative sample of the fuel-oil users in the areas where winter had put a heavy drain on oil supplies was asked, "Have you done anything or tried to do anything to help out on the fuel-oil shortage?" and 78 per cent replied that they had. When asked to say specifically how they had helped, 53 per cent said they had reduced temperatures in their houses, 12 per cent said they had used less oil, 10 per cent said they had shut off more rooms, and 17 per cent mentioned other measures. This evidence, fortified and reemphasized by several subsequent studies, amply illustrates the consumer cooperation received by the oil industry. For that cooperation and the spirit in which it was given, we are all grateful.

Among the examples of cooperation from Federal authorities we should cite their

1. Turning over 187 tankers to private industry to augment the carrying of oil by sea.
2. Raising the permissible load line of tankers so as to increase their carrying capacity roughly 6,000 bbl per ship.
3. Working to keep waterways open to barge traffic in the winter of 1947–1948. (Nearly 2 million more barrels of oil were moved on the Illinois waterway than in the previous winter because the Army Engineer Corps fought zero weather with special ice-breaking equipment.)
4. Reimposing export controls on critical products (there controls appear to be no longer needed).[15]
5. Giving prompt approval to a decentralized set up of industry committees to handle emergency shortage situation at the consumer level.
6. Issuing instructions to government agencies and appeals to the public to conserve products.
7. Lending supplies of fuels from the Navy stock pile to alleviate shortage conditions in certain critical areas.

As unbending believers in the superiority of free enterprise as against government action, we may be permitted, I hope, to temper our acknowledgment of cooperation from the Federal government by pointing out that some of it came dangerously near being, as governmental action so often is, "too little and too late." The 1947–1948 winter's fuel-oil crisis on the east coast would have been much less troublesome if the tankers had been released to private industry more promptly.

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[15] Export controls have since been removed.—EDITOR.

Also, we cannot list under C for Cooperation the 18 separate studies and investigations of the oil-supply problem and of petroleum-industry affairs conducted by committees and other agencies of Congress. Oil companies must ever stand ready to explain and justify their acts and policies to the representatives of the people. But in our own affairs we would be inefficient indeed if we had agency after agency, committee after committee, pawing over the same sets of facts and coming up with a chaos of muddled understanding and misunderstanding, mistaken conclusions, and no conclusions at all. Thousands of hours of the time of busy executives have been devoted in the last year to production of reports for this committee and that, to appearances in Washington and elsewhere at committee hearings, and to dealing with conditions caused by scarehead publicity issuing from Congressional hearings. We would welcome, or even seek, intelligent investigations by the Administration or by the Congress of any condition in our industry that involves the public welfare. However, it should be possible for the desired end to be attained in one investigation by one thoroughly competent committee, commission, or other agency, with time allowed for adequate preparation of an orderly presentation by the industry. Such an investigation should resist the temptation to make scare headlines and should concentrate on a serious attempt to understand the function of oil in the national economy and the problems, abilities, and competitive forces of the industry.

Most state and local authorities acted with promptness and intelligence during the winter to provide coordination of efforts to deal with specific hardship conditions. Operations such as those directed by Coordinators Madler in Wisconsin and Leonard in Michigan, to cite only two of the many who deserve recognition, quickly demonstrated that the trouble spots were localized and small. They were promptly alleviated by cooperative action within the petroleum industry, with state and local authorities serving mainly as umpires between companies and as administrators of reassurance to local public opinion where it showed symptoms of hysteria. The combination of the administrative experience of state and local officials with the oilmen's know-how proved effective in cutting the crisis down to its real size, which was smaller than most oilmen had feared it might be.

The railroads cooperated in solving the critical transportation difficulties by promptly handling a large volume of tank-car shipments over unusual routings. Strictly emergency shipments were made in a total of 489 cases in 16 states alone, and in addition hundreds of trainloads of crude oil and products were moved to the centers which were in short supply. This movement supplemented capacity operation of pipe lines.

The steel industry has aided by supplying, to the maximum permitted by other demands, the steel needed for the industry's expansion of drilling, pipe lines, and construction of refinery equipment.

To the great majority of manufacturers of oil-heat devices we owe a special kind of debt. It was within their power to make and market more units than the oil companies could take care of over and above the number already being fed. Not to sell meant in their case foregoing opportunities for profit. There was a time when it looked as if unwise policies of driving ahead in selling burners, with reckless unconcern about how the buyers would get fuel oil, would prevail. Wiser and more enlightened policies, however, have come to the fore. Most of the oil-heat equipment manufacturers concentrated in 1949 on replacements of old and inefficient units, with a reasonable number of new installations. Their tying of their sales to due concern regarding the customer's ability to obtain a continuing supply of fuel is both good business and praiseworthy cooperation in holding the demand for oil within satisfiable limits.

We could not have attained the present comfortable position regarding fuel-oil supplies if sales of burners and space heaters had continued at the terrific pace set in 1947. We offer our thanks to the sales forces in the burner industry for helping us to slow that pace.

My second C, Conservation, was of two sorts, carried out, respectively, by the industry itself and by customers.

Aided, and in some cases compelled, by state legislative or regulatory bodies, the industry has been steadily advancing in the adoption of efficient methods of conserving gas that was once flared, of recovering natural gasoline and distillates from gases, and of repressuring and recycling gas through underground oil reservoirs. These measures prevent waste and work toward maximum recovery or production from existing wells. Today tremendous sums are being expended by oil producers on such conservation and secondary-recovery methods in the oil fields. The production of liquefied petroleum gases has been expanding at the rate of around 30 per cent per year for several years. While this requires major capital expenditures, the higher prices of crude and products make possible resaonable pay-outs. Conservation is not only necessary as a means of stretching supply to fit consumer demand and as sound national policy—it is also good business. . . .

The final, and I think the most vital, factor in licking scarcity problems has been Competition. This statement may surprise those who complain that competition was largely eliminated during the supply crisis. It was not eliminated. During most of the last year there was, to be sure, a sharp decline in attempts to take each others' customers and outlets by means of cut prices and other inducements of the lush supply era. But there has never been such intense competition by each and every company in the important job of trying to take care of its own customers almost regardless of costs and thus retain their good will and hold their business for the future.

Yes, competition is at work as much in times of short supply as it is in days of oversupply, only it works in different ways—in ways that prove the superiority of a free economy over any kind of government planning.

Not competition for the consumer's business but determined and untiring competition for the supplies to fill his orders licked the 1947–1948 supply problem. Can you imagine companies hauling trainloads of crude and products thousands of miles every day from remote points to refineries and customers for any reason except to show their ability to take care of their customers' needs? Certainly they did not do so for present profit, for there was generally a direct loss in the operation.

The lengths to which companies went to meet the crisis is a long story that will never be fully told. Abnormal freight costs, emergency deliveries by truck from far-distant points, and heavy overtime became normal practices. Competition alone explains the tremendous drive producers have put on to find more oil, the building of new refinery units, the opening up of old refineries and operating obsolete submarginal units of refineries, the extension and enlarging of pipe lines, and the addition of tankers and barges to the water-borne oil-carrying fleet on the scale of the last two years. It is competition that has prodded the industry into pouring nearly 5 billion dollars into new facilities since 1946, spending more for that purpose each year than its total net earnings, and seriously enlarging the debt it must manage in an unpredictable future.

Competition for ever larger supplies has kept the wheels going around in accelerating tempo. Imagine what would have happened if government had stepped in, as many urged, and started pooling and rationing the scant supplies to last the winter among all consumers. Immediately all incentive for rival companies to try to outdo each other in caring for their respective customers would have died. The responsibility would have been on government. No company would have had anything to gain by incurring abnormal costs to take care of the customers of a government pool.

Without competition the solution of the supply problem in this country might have been what it is in Russia—a failure in spite of stern coercive measures by government; or it might have been what it is in England—mere division of scarcity without effort or incentive to supplant it again with abundance.

Is the consumer in America paying too dearly for the luxury of having more and more? In this time when prices of commodities and wages have been advancing generally, prices of petroleum products have, of course, also advanced. They are 22 per cent higher than in 1926. But the average for commodities in general is up 69 per cent. As compared with the last postwar inflation in 1920, all commodities cost 9.7 per cent more, but petroleum products cost 33.5 per cent less. The average factory worker in the United States can buy 5 gal of gasoline today with the same hour of labor that would get him only 4 gal in 1941. And the farmer's bushel of wheat or corn will buy him about 8 gal of gasoline instead of the 4 he could buy in 1941. No wonder more petroleum products are being used on the farms than ever before!

Competition of company against company has not only licked the supply problem—it has continued to function in regulation of prices to the obvious advantage of the consumer. Of the 50 commodity groups in the government's wholesale price index, 41 show greater increases than do petroleum products.

Yes, we have licked the supply problem of 1947–1948. But in a sense the supply problem is never licked. The question of adequacy of supplies is one that will always be with the petroleum industry. Despite the breathing spell that our recent forced-draft expansion has given us, there remains need for continued vigilance and continued striving to be ready for the new demands we are sure to meet if our nation's progress continues.

Our first, and in many ways our biggest, job is to keep on finding and developing more crude production. We must discover more than 2 billion barrels of new reserves each year if we are to keep ahead of depletion, and this means we must go farther and farther afield into the mountains, the swamps, and the tidelands and continue to drive the drill deeper and watch for even, thin sands all the way down. Secondary-recovery efforts must be further stimulated, and the conservation of gas and liquefied petroleum gases must be extended until no usable hydrocarbon is wasted.

Foreign oil sources must be further developed. Certainly the Eastern Hemisphere should be placed as quickly as possible in the position where it at least supplies its own needs, and only American drive, technology and capital can accomplish this result. Research and development must be continued with respect to methods of making synthetic fuels from nonpetroleum sources.

In addition to taking care of heavy obsolescence of refining and transportation facilities, we must apparently continue, until there is some marked interruption in the growth in demand, to expand all our facilities at the rate of around 7 per cent per year. More tankage must be provided to take care of the growing peaks and valleys in demand produced by expanding winter usage of fuel oils.

All these things require heavy capital investments, and we must find ways of meeting this. The industry is understandably reluctant to do much further borrowing on top of what it had had to do the past few years, and it is evident that continued good earnings are the prime essential to our ability to raise this needed capital. In 1947, capital expenditures were 70 per cent in excess of total industry earnings. An increase in corporate taxes at this time would make it impossible to continue the industry's expansion program and would have serious effects on our whole economy.

I am convinced our industry can and will achieve the necessary growth if it continues to enjoy the cooperation of the public, governmental authorities, and other industries, if it continues its diligent efforts in conservation, and if it is permitted to preserve the keen rivalry and the support of research and technology that has distinguished its brand of private enterprise.

No part of our past or future is more important than free competition. Competition cannot be effective in the public interest if the government is to mark out more and more areas in which, or methods by which, we are forbidden to compete. The one thing we must have if we are to continue to meet our growing demand and responsibilities is an atmosphere of freedom and a reasonable hope of reward for individual initiative and ingenuity—an atmosphere that is as essential to our economic security and progress as is the air we breathe.

Chapter VII

OUR SUPPLEMENTAL PETROLEUM RESERVES[1]

By Eugene Ayres

Gulf Research and Development Company

Introduction

It has been assumed for the purposes of this report that all substances from which present technology can provide substitutes for petroleum or petroleum products are considered supplemental reserves; these reserves include coal, oil shale, tar sands, natural gas, and agricultural materials. This definition does not mean, however, that petroleum substitutes made from these substances are now available or, necessarily, that they can be made available under existing conditions any more than metals such as gold or silver can be used as a practical substitute for lead, even though the properties of gold and silver make them adaptable to many of the purposes for which lead now is used.

Some of the supplemental reserves have been referred to carelessly or ignorantly as a resource that may adequately protect the nation in time of emergency or in the event of shortage of petroleum. It is highly important that the difficulties and limitations involved in replacing part or all of the country's petroleum requirements with products obtained from these supplemental reserves should be understood and appreciated. This is vital to effective planning for national defense and for national stability and progress.

[1] Revised in August, 1948, from a pamphlet by K. C. Heald and Eugene Ayres, "Basic Statistics of North-American Supplemental Reserves," The Gulf Companies, Pittsburgh, May 15, 1944.

Since the revision of this report, no information has been published that radically alters the general picture as described here. Additional data appearing in "Synthetic Liquid Fuels 1948 Annual Report of the Secretary of the Interior" are worthy of mention. Forthcoming data from plants scheduled for completion by the end of 1949 will be of considerable economic significance.

A very cursory tabulation of the quantities of oil shale, coal, and tar sand in this country and Canada makes it apparent that, if the products which will satisfactorily replace petroleum products could be secured from these materials at a price which would not seriously handicap the present consumers of petroleum products, domestic requirements would be met for generations. The problem, therefore, is not one of scarce raw materials in the form of oil shale or coal but is instead an economic one, which may or may not be solvable as long as crude petroleum is obtainable either in this country or abroad at current or materially higher prices. These supplemental reserves must be regarded as existing but unavailable until technology develops methods for securing from them substitute petroleum products at prices not greater than those of equivalent products made from crude petroleum.

In time of emergency, cost might play only a minor part, because very great reserves of man power and raw materials of kinds now considered critical would be essential to develop from these supplemental reserves enough petroleum substitutes to meet a significant part of the emergency demand, and the development would require the even more critical element, time. It is important that all of the critical factors should be appreciated.

An attempt is made in this report to furnish somewhat more realistic estimates of the amounts of these supplementary reserves than have been current during recent years and to give a coherent picture which will indicate what these reserves are, something of their magnitude, some of the economic factors involved in their development, and some of the present uncertainties with regard to their most effective utilization.

It should be emphasized that figures for investment and operating costs, appearing in the following material, must be considered only as indications of a comparative nature, since these costs will vary with improved processing methods as well as with constantly changing costs of construction and wage levels. Furthermore, any estimate can be markedly influenced by the size of the plant and its location, which will govern the investments for such things as water supplies, transportation, and housing.

The available data on these reserves are far from complete. In regard to coal, no commercial coal-hydrogenation plants or Fischer-Tropsch plants have yet been built in the United States. However, both industry and the government are currently engaged in greatly expanded research programs aimed toward the economic manufacture of synthetic fuels by coal-hydrogenation and coal-gasification processes. Two research combinations of oil and coal companies have been formed for the more active prosecution of developments along this line. Coal carbonization has drawbacks for large-scale use because of extremely large by-product production of coke. In recent years, a revived interest has been shown in shale-oil research. Work now being carried on by industry and government is beginning to provide pertinent information for a potential oil-shale industry. Data on oil and tar-sand reserves, although they are being augmented by Canadian provincial governmental and industrial research, nevertheless are still largely conjectural. To what extent reserves of oil sand can be counted on to relieve a shortage of natural petroleum remains questionable. Natural gas can be used as a raw material for Fischer-Tropsch synthesis, but resources are even more limited than those of petroleum. Despite the fact that one commercial natural-gas synthesis plant is said to be now under construction, future wide-scale operations will necessarily be limited by the changing economic picture and by the number of suitable plant sites where adequate gas reserves and water supplies are available. Agricultural materials hold little promise as a source of economic liquid-fuel substitutes for the United States or as a source of fuel oils and lubricants.

Despite the limitations on the available data, it has been possible to find fairly representative figures on many of these supplemental reserves. In many cases, however, it was necessary to extrapolate data from estimates for small plants. Figures obtained may be compared only with extreme caution, but Table 1 presents a rough summary of some of the data compiled in this report. Reference should be made to the text for the interpretation of each figure.

Possible Trend of Development. Since it is dangerous to prophesy in technical matters, the following analysis is offered merely in an attempt to polarize thought in connection with the general statistical study.

1. A limited number of Fischer-Tropsch plants for the conversion of natural gas to specialized petroleum products are likely to be built and operated by petroleum companies. The experience gained from this work may be applicable to the broader problems of the Fischer-Tropsch synthesis from coal.
2. Industry and government will continue their studies on con-

tinuous gasification of low-grade coal above and below ground with the idea of getting into large-scale production of gasoline by Fischer-Tropsch synthesis. Subbituminous coal or lignite will be used.

TABLE 1. ROUGH SUMMARY OF DATA*

	Coal hydrogenation†	Coal—Fischer-Tropsch†	Oil shale	Tar sands	Natural gas	Crude petroleum
Total United States reserves, billions of tons of source material	500‡	500‡	>400	>500	4	
Percentage of total reserves most practical for exploitation	25	50–100	?	1	20	
Potential yield from reserves suitable for exploitation, billions of bbl. of gasoline	125	375–750	365	2	2.8	20–40
Cost of gasoline, cents per gal	14–23	7–19	8–16	?	5–13	6–?
Investment, dollars per bbl. of gasoline per day	6,500–14,300	2,950–10,000	3,100–8,400	1,335–3,300	2,200–8,200	1,500–3,000

* Figures presented in this table indicate the range of estimates only. The text should be consulted for discussion of individual estimates and details on which they are based.

† Coal hydrogenation is based on subbituminous coal alone. Coal—Fischer-Tropsch is based on all coal, including subbituminous.

‡ Total recoverable reserves of coal are taken as intermediate between the lowest and highest of recent estimates.

3. Unless or until radically new technology is discovered, high-pressure hydrogenation of coal to gasoline will not be developed but hydrogenation of tars and residual oils may be practiced widely.

4. The Fischer-Tropsch process will not yield a cheap heavy fuel oil. This can be made either by low-pressure hydrogenation of coal or by the retorting of oil shale.

5. For a long time to come, no important amount of coal other than subbituminous and lignite will be used for synthesis.

6. The working of oil shales will depend on improvements in mining and processing operations. It is still too early to forecast the role of shale oil in supplying substitute petroleum products.

7. Tar sands will be worked to a limited extent but will be an unimportant source of substitute petroleum.

COAL

Somewhat more is known about the coal resources of the United States than is known about oil shale and tar sand, the other important supplementary petroleum reserves. Their nature, extent, methods of mining, and many uses have been intensively studied by scientists and industrialists alike.

Coal made an important contribution to the emancipation of this country from industrial domination by Europe. It supplied the energy that activated the machines in factories and mills, that permitted the mining and the smelting of our minerals, that carried raw materials and finished products to all parts of our own country and to all parts of the world. Even in this day of enormous production and use of petroleum and natural gas and remarkable development of water power, more than half of the total energy used in the form of power, light, and heat in this country comes from coal. The nation's expanding civilization, however, has become dependent on some products which thus far have been produced in quantity only from petroleum, but it is not impossible that on some future day coal will provide many if not all of these products which have become so indispensable.

The essential component of all coal is carbon, associated with variable amounts of volatile matter. All coal also contains moisture, some sulfur, and inert material or ash. On the basis of the proportionate amounts of fixed carbon, volatile matter, and moisture: coals are ranked as anthracite, bituminous, subbituminous, and lignite. Coals are also classified as types depending on appearance: bright, semisplint, splint, cannel, and Boghead. Thus a bituminous coal may be a bright coal, or a splint coal, or a coal of some other type.

The chemical composition of coal is determined not only by its rank but also by its type. For example, a bright bituminous coal may contain 61 per cent fixed carbon, and a splint coal from the same bed in the same mine may contain 74 per cent fixed carbon. The bright coal may contain more than twice as much sulfur as the splint coal, and the heating value of the one may be substantially different from the heating value of the other.

Coals are relatives belonging to the same family, but this does not mean that they all look alike or behave in the same way or that they will be equally useful as a supplementary petroleum reserve. On the contrary, it may be anticipated that experience will allow the classification of coals in terms of their suitability for conversion into liquid hydrocarbons. Presumably the characteristics that will best adapt a coal for conversion by one process will not necessarily prove to be the same as those that will adapt a coal for conversion by another process. This fact has been indicated by tests in which coals of different ranks and types were hydrogenated under standard conditions of temperatures, pressure, and time and with the same catalysts. Some coals yielded twice as much liquid hydrocarbon as did others but gave more process difficulties than did the lower yielding coals. There is no doubt, therefore, that some coals will prove far better suited for conversion into synthetic oil than will others.

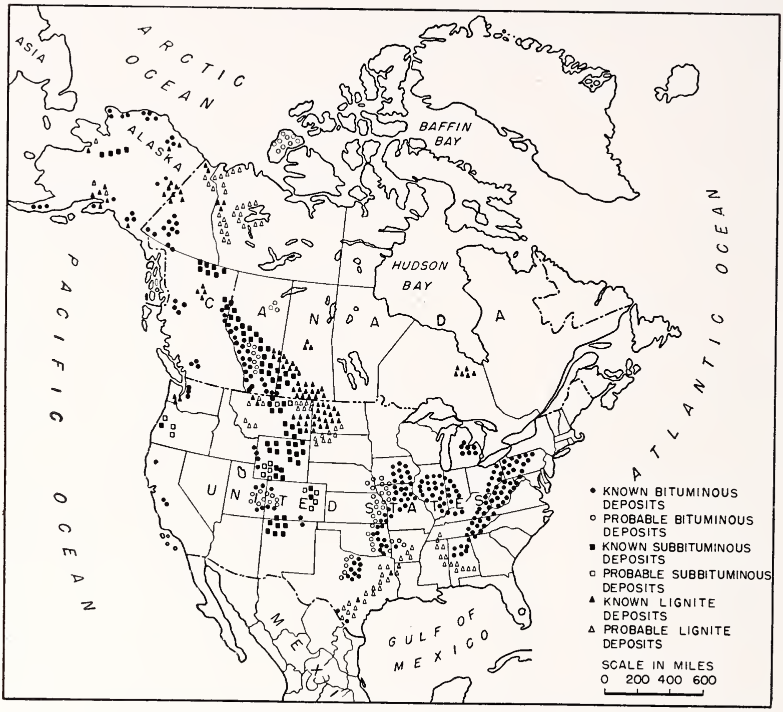

FIG. 54. Location of North American coal deposits.

Geographic Distribution of Coal. The accompanying map shows the general distribution of the known and probable coal deposits in the United States and Canada. Anthracite is not shown on this map since its value as a residential fuel, its limited supply, and its relatively high cost of mining combine to establish a price level above that of other coals. It seems improbable that producers of synthetic petroleum would pay a premium for anthracite when their needs could be better supplied by a cheaper coal.

Bituminous coal is more valuable for most of the purposes for which coal now is used than are subbituminous or lignite coals. These lower rank coals have higher moisture contents and lower heating values and deteriorate more rapidly when stored than does bituminous coal. It would be advantageous from many standpoints to use lignite and subbituminous coal rather than bituminous coal for the production of synthetic oil, and it happens that present technology indicates that processes can be designed which will make them even more suitable for synthetic-oil production than the higher ranking coal.

Geologic Occurrence. Most of the coal in the world is found in rocks of Mississippian age or younger. The greatest deposits are in formations belonging to the Mississippian, Pennsylvanian, Cretaceous, and Tertiary periods. No coal is present in the older Cambrian, Ordovician, and Silurian rocks, and there is little in the Devonian rocks, because coal was formed from accumulations of plant material, and no evidence can be found that land plants existed prior to Devonian time. During subsequent periods, there were tremendous forests which supplied the plant material for the coal deposits.

The geologic evidence is clear that most of the coal in the world was formed in fresh-water swamps, and as would be expected, the associated rocks are shales and sands deposited by the streams which flowed into and near such swamps. This is in contrast to petroleum, which characteristically occurs in beds that were laid down under the sea. Petroleum is found in many localities, either in porous limestone or associated with thick limestone formations, whereas the coal-bearing formations are characterized by a scarcity of limestones.

Individual beds of coal range in thickness from a fraction of an inch to more than 100 ft. Some beds, like the Pittsburgh coal of Pennsylvania, underlie hundreds or even thousands of square miles; others have small lateral extent. As a general rule, several separate minable beds are found in a coal-bearing area. The beds of coal may be horizontal, inclined, or even vertical, conforming in attitude with the associated rocks.

The great coal-bearing areas are regional synclines or structural basins, but local disturbance of the strata may tend to obscure the regional relationships. There may, within the regional syncline, be uplifts or anticlinal warpings of the formations that, although minor when compared with the great synclinal depression, are themselves tens of miles in length.

Since many of the oil fields of the world also are located in great structural basins, oil fields and coal fields may exist in the same general area, in some instances the one overlying or underlying the other. Neither, however, can be used as an indication of the probable presence of the other. Oil is found in some regions where there is no coal at all, and, conversely, coal occurs in many areas where there is no oil.

Procedure by Which Tonnage of Coal Has Been Estimated. "The question of 'ultimate recoverable reserve' of coal has been confusing because of three things. (*a*) Strictly speaking, the entire reserve is recoverable if we are willing to spend enough money. But what we have rather vaguely in mind is that 'recoverable' means 'recoverable at a reasonable cost,' and the meaning of 'reasonable cost' depends pretty largely upon the technologist's state of mind. (*b*) When we dig down where geologists say there should be coal, we sometimes find that there is no coal. Estimation of any resource underground is not an exact science, and coal, in some localities, is erratic in its conformations. (*c*) Widely quoted figures from United States geological surveys have been wrongly construed as proved reserves. Instead, they are geological estimates of coal deposits without regard to recoverability or cost.

"In 1907 and then in 1936, geological surveys were made which indicated that the United States reserves (prior to the start of mining) had been 3.2 trillion tons. But the reserve figures include deposits which are regarded as unrecoverable in a practical sense. The Bureau of Mines is now making a careful study, in cooperation with industry, to determine present practically recoverable reserves. They will arrive at net figures by subtracting production and losses, and the figures for reserves prior to the start of mining will be reexamined in the light of more modern geological and mining data. Until this study is completed (several years hence), we shall have no authoritative picture of our present recoverable coal reserve" (18).[2]

Apparently the most authoritative estimates at this time are 1.6 trillion tons as a maximum and 0.3 trillion tons as a minimum.

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[2] Numbers and pages in parentheses refer to the bibliography at the end of this chapter.

Availability of the Supplementary Reserves of Coal. Knowledge concerning location, extent, and methods by which coal may be mined is adequate. The existing coal mines of the United States can supply a greater tonnage of coal than can be consumed by our peacetime industry when that industry is operating on the 1940 scale. At least some raw material could therefore be made available for the production of synthetic hydrocarbons without opening new mines or establishing a new mining industry, although the surplus that could be secured from existing mines would supply but a comparatively small part of the petroleum requirements of this country, and there are no substantial mining facilities for the types of coal that appear to be best suited to hydrogenation.

Furthermore, processes by which coal can be converted to liquid fuel and other petroleum products are in operation in other countries, and American technologists have the information that would allow them to install these known processes if such installations were justified by national security without reference to economics. Coal, however, is not and cannot be considered an available supplementary reserve in an economic sense until liquid hydrocarbons and, in particular, synthetic gasoline can be secured from it at a price no greater than these same products can be secured from other sources. The processes for liquefying coal, as they are now known, cannot force their products through this economic barrier.

Furthermore, coal cannot be considered a safeguard against a sudden emergency demand for a large increase in our available oil until an industry of some magnitude has been established, experience has been gained, and a large group of technologists and workers have been educated in the business of constructing and operating the plants to convert coal into gasoline and some of the other very essential products that are now secured from petroleum.

Coal Hydrogenation

Discussion of Data. To date, no commercial coal-hydrogenation plant has gone further than the planning stage in the United States. However, the Bureau of Mines, starting from data obtained from German plants and from the hydrogenation works at Billingham (England), is currently conducting pilot-plant research on coal hydrogenation in a 200 bbl per day demonstration plant at Louisiana, Mo. It is probable that a plant based on present knowledge would use subbituminous coal and would yield at least 1 bbl of gasoline from 1 ton of coal (including coal requirements for power generation, steam, hydrogen, and process material). The bituminous grade would give a higher yield of 1.25 to 1.67 bbl of gasoline per ton, while lignite would yield only 0.77 bbl per ton (27, p. 8).

The man power for operation and mining per barrel of synthetic gasoline should range from about the same as present man-power requirements for gasoline from petroleum (other products neglected) or perhaps somewhat greater (13, p. 45). The steel requirements for the construction of coal hydrogenation plants are at least four times those of conventional petroleum refineries per barrel of gasoline per day.

The investment required for coal-hydrogenation plants per barrel of gasoline per day would probably be about $10,000 (47), while the investment in mining operations would add about $3,000.

Ordinarily, coal would be hydrogenated directly to gasoline, and substantially no other petroleum products would be obtained. It is technically possible, however, to secure diesel fuels also, some sort of lubricating oil, and wax. A cheaper hydrogenation process can be applied to coal for the production of heavy fuel oil alone.

By conventional high-pressure hydrogenation of subbituminous coal, a gasoline of 70- to 75-octane number can be produced in 20 to 25 per cent yield (based on total coal), and by a type of hydroforming (or second catalytic hydrogenation) this can be increased to 85- to 90-octane number with about 25 per cent reduction in yield. The gasoline is highly aromatic rather than isoparaffinic.

The middle oil fractions (boiling 210 to 330°C) contain about 20 per cent tar acids, which are a potentially valuable although too abundant source of phenols. After removal of these phenols, the raffinate is said to be suitable for diesel fuels. The heavier oils either can be recirculated for gasoline production or can be put through a series of expensive steps for the manufacture of an inferior lubricating oil.

Coal Reserves for Hydrogenation. According to present technology, subbituminous coal is the only grade of coal which would be used for hydrogenation unless or until improved processes are developed. Anthracite coal can be disregarded, not only because of its small amount and its high price but also because of its process difficulties. Bituminous coal is capable of giving a higher yield of liquid fuel but presents operating difficulties. Lignite gives a lower yield of liquid fuel but could be used after the supply of subbituminous coal had been substantially depleted.

It is interesting to note that 85 per cent of the subbituminous coal is in Wyoming and Colorado and that nearly all of the lignite is in Montana and North Dakota. Neither material is found in the East.

Oil Yields. A. C. Fieldner of the Bureau of Mines and his associates estimate that 0.6 to 0.8 short ton of bituminous coal, 1 ton of subbituminous coal, or 1.3 tons of lignite are necessary for production of 1 bbl of gasoline by hydrogenation (27, p. 8). This estimate includes coal (or lignite) required for power, steam, and hydrogen. In a more recent statement, however, Fieldner reveals that the Bureau's plant will produce 200 bbl of gasoline per day from 65 tons of bituminous coal with an equal tonnage of coal needed for power, steam, and hydrogen, the total coal requirement thus being equivalent to 0.65 ton per barrel of gasoline. Should natural gas rather than coal be used as a source of hydrogen, it would be reasonable to expect that total coal requirements will be reduced about 30 per cent (26; 13, p. 45). Table 2 presents the data on oil yields from coals assayed in the Bureau of Mines experimental plant (7, p. 176). Particular attention should be paid to the columns headed "Yield of assay oil," "Ultimate yield of gasoline," and "Net yield of gasoline"; the last gives figures comparable with those previously quoted. It might be noted further that it is generally conceded that the high-yielding bituminous coals are at present the hardest to liquefy, while the subbituminous and lignite coals in general liquefy more easily (7, p. 426).

Costs of Production. The estimates appearing in the recent literature are numerous and somewhat divergent. Probably the most reliable are those of the Bureau of Mines, which place the cost of coal-hydrogenation gasoline at between 14 and 19 cents per gallon, without consideration of by-product credits (13, p. v; 47). Charges based on construction cost of the plant account for a large portion of this cost, depreciation alone amounting to 35 per cent (13, p. 40). Moreover, Schroeder (46) states that production and compression of hydrogen account for about 50 per cent of the production cost. If natural gas rather than coal were used as a source of hydrogen, a considerable reduction in production cost might result. A further reduction of 3 to 5 cents per gallon, it is estimated, might be charged for by-product credits.

TABLE 2. COALS ASSAYED IN BUREAU OF MINES EXPERIMENTAL PLANT*

Origin and rank of coal					Analyses, per cent					Yield of assay oil				Ultimate yield of gasoline†				Net yield gasoline, gal. per ton of total coal used in process
					As mined			Moisture and ash-free		Weight, per cent		Gal. per ton†		Weight, per cent		Gal. per ton‡		
State (1)	County (2)	Coal bed (3)	Mine (4)	Rank (5)	Moisture (6)	Ash (7)	Volatile matter (8)	Carbon (9)	Oxygen (10)	Moisture- and ash-free coal§ (11)	Coal as mined (12)	Moisture- and ash-free coal§ (13)	Coal as mined (14)	Moisture- and ash-free coal§ (15)	Coal as mined (16)	Moisture and ash-free coal§ (17)	Coal as mined (18)	(19)
Alabama	Jefferson	Mary Lee	Sayreton	Bituminous, high-volatile anthracite	4.2	9.8	27.0	86.9	5.0	60	52	159	138	42	36	122	106	55
West Virginia	Monongalia	Upper Freeport	Indiana Colliery No. 21	Bituminous, high-volatile anthracite	3.2	8.0	30.0	86.6	5.7	70	62	185	164	49	43	142	126	66
Pennsylvania	Allegheny	Pittsburgh	Bruceton‖	Bituminous, high-volatile anthracite	1.6	6.3	37.0	84.2	6.8	70.5	64	187	170	49.5	45	148	130	68
Alabama	Walker	Black Creek	Empire¶	Bituminous, high-volatile anthracite	2.7	2.9	36.0	84.3	7.5	70.5	66¶	187	175¶	49.5	46¶	148	134¶	70
Utah	Carbon	Lower Sunnyside	Columbia	Bituminous, high-volatile bituminous	5.5	4.9	38.8	82.1	9.5	75	67	199	178	52.5	47	152	136	71
Alaska	Matanuska	Upper Shaw	Eska¶	Bituminous, high-volatile bituminous	3.7	6.8	41.8	81.0	10.5	73	67¶	193	178¶	51	47¶	148	136¶	71
Indiana	Vigo	Indiana No. 4	Saxton No. 1	Bituminous, high-volatile coal	13.6	7.3	34.2	80.9	9.5	70	55	186	146	49	38.5	143	112	58
Illinois	Franklin	Illinois No. 6	Orient No. 2	Bituminous, high-volatile coal	7.8	6.5	33.7	80.6	10.0	70.5	60	187	159	49.5	42	143.5	122	63
Washington	King	Strain-Upper McKay	Black Diamond	Bituminous, high-volatile coal	9.6	3.7	40.1	78.6	12.5	68.5	59	182	156	48	41	139	120	62
Colorado	Weld	....	Puritan	Subbituminous, bituminous	24.1	4.1	29.1	76.6	16.4	63	45	167	119	44	31.5	128	91	63

Montana	Rosebud	Rosebud	Colstrip	Subbituminous, bituminous	25.1	7.6	28.5	76.7	16.2	60	40	159	106	42	28	122	81	42
Wyoming	Sheridan	Monarch	Monarch No. 45	Subbituminous, bituminous	23.2	3.9	31.2	75.6	16.9	68.5	49	182	130	48	34	139	100	52
North Dakota	Mercer	Fort Union	Beulah‖	Lignite	34.9	8.0	26.0	73.0	19.4	54.5	31	144	82	38	22	110	63	33
North Dakota	Ward	Coteau	Velva‖	Lignite	39.5	4.5	26.0	72.0	21.4	52	32	138	85	36	22.5	106	65	34

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* Source: A. C. Fieldner, Chief of Fuels and Explosives Service, Bureau of Mines, Department of the Interior (7, p. 176).

† Calculation based on assumption of 70 per cent by weight of assay oil converted to gasoline.

‡ Assay oil assumed to have 265 gal. in 1 ton (2,000 lb) and gasoline, 290 gal.

§ Calculation based on moisture- and ash-free coal.

‖ Name of town.

¶ Figures are for "coal as mined and washed" for columns (12), (14), (16), and (18) for Utah and Alaska coals.

It is not practical to estimate costs per barrel of oil produced, since the hydrogenation of coal usually proceeds in two steps when gasoline is the desired product; the first step is designed to liquefy coal and recycle the heavy oil formed, while the second step hydrogenates the middle oil from the first step and recycles all fractions heavier than gasoline. It is possible to hydrogenate coal in one step to yield fuel oils as the desired product instead of gasoline, or it is possible to obtain gasoline, kerosene, and fuel oils by variations in the two-step process, but comparable data on a cost basis are not at hand.

Man-power Requirements. In 1944, the average production of bituminous coal per man-day was 5.67 tons (30). It should be noted that in certain localities, especially by strip mining, the amount of coal producible per man is greatly increased (14.23 tons per man-day in 1938, with some localities reporting as much as 68.54 tons per man-day), but the figure of 5.67 tons per man-day was the 1944 national average. No figures as to the man-day output of subbituminous coal are immediately available, but assuming for the sake of an estimate that they are the same as for bituminous coal it may be estimated that 17,600 men would be required to produce subbituminous coal for 100,000 bbl daily of synthetic gasoline.

Average production of lignite in 1944 was 12.95 tons per man-day (41), so that approximately 10,000 men would be required to mine the coal (130,000 tons) needed to produce 100,000 bbl of synthetic gasoline daily. Again, fewer men would be required for stripping operations.

Dr. Gustav Egloff of the Universal Oil Products Company has testified (7, p. 121) that the British plant which produces 3,000 bbl of gasoline daily requires 6,000 men to produce the coal, de-ash it, wash it, grind it, and process it through the hydrogenation plant. On this basis 200,000 men would be required for the entire work of producing 100,000 bbl of gasoline per day, but this figure has little or no value since it is based upon data from a small plant.

Few published data are available as to the man power which would be required to operate coal-hydrogenation plants other than the figure given by Dr. Egloff, who stated further that it could be greatly reduced in America. There is little reason to believe that man-power requirements would greatly exceed those for modern production and refining operations. The drilling and production of some 1.25 billion barrels of oil in 1939, which yielded upon refining some 550 million barrels of gasoline, required about 170,000 workers for drilling and producing and 100,585 workers for refining (transportation employees omitted). Thus, for the production of 100,000 bbl daily of crude oil, approximately 4,960 men were required in 1939, while the total man power required for producing 100,000 bbl of gasoline daily was approximately 18,000 men. This last figure is high since it disregards the fact that an equal volume of products other than gasoline was produced.

An extrapolated figure for coal hydrogenation, based on private data on England's small plant (23), yields a rough figure of 6,000 men for a plant to produce 100,000 bbl of gasoline daily, and this source (23) states further that, since this estimate is based on a small-scale plant, a more exact guess might be 2,000 men. The range between 2,000 and 6,000 is wide, but no better figures are available.

It may therefore be said that man-power requirements for gasoline production by coal hydrogenation (including mining) would be at least as large as those for gasoline production from petroleum (including oil production), or possibly twice as high.

Steel Requirements. Various estimates have been presented (7, pp. 38, 175) as to the amounts of steel which would be required for the construction of plants to produce gasoline by coal hydrogenation. These estimates vary from 8.3 to 14.1 tons per daily barrel of gasoline; hence plants to produce 100,000 bbl of synthetic gasoline daily would require 830,000 to 1,410,000 tons of steel, with the probable figure much closer to the lower estimate. Gasoline production from petroleum (other products disregarded) requires from 0.7 to 2.0 tons of steel per daily barrel; hence coal-hydrogenation plants require for the same gasoline output at least four times as much steel as petroleum refineries.

Investment Required. Based on recent Bureau of Mines research, W. C. Schroeder has estimated an investment requirement of $10,700 per daily barrel. This estimate, unfortunately, is unqualified as to type of raw material utilized and nature of the product on which it is based. However, inasmuch as the gasoline is by far the highest quality product of coal hydrogenation, it can be assumed that as great a proportion of the products as possible will be gasoline. A further assumption, which may not be entirely justifiable, that other than gasoline liquid products can be converted to gasoline in almost 100 per cent yields makes Schroeder's estimate equivalent to 1,070 million dollars for a capacity of 100,000 bbl per day. This figure applies to plants using coal as source of hydrogen. As Mr. Schroeder remarks, should natural gas constitute the source of hydrogen, the capital investment would be somewhat reduced (47).

The investment for plants to produce fuel oil is considerably lower. The Bureau of Mines has prepared two estimates. For a plant to produce 21,100 bbl per day of ash-free fuel oil plus by-product gasoline and liquefied fuel gases, an investment of approximately 130 million dollars is required, equivalent to 617 million dollars for 100,000 bbl per day fuel oil capacity. On the other hand, a plant producing the same quantity (21,100 bbl) per day of heavy fuel oil (about 500 SSU viscosity at 170°F) containing "all the solids from the process" would require an investment of about 63 million dollars, equivalent to 300 million dollars for 100,000 barrels of low-grade fuel-oil capacity (13, p. 40).

The range of $1 to $10 per ton-year covers the investment required for coal mining (the low figures being for strip mining and the high ones for shaft and difficult drift mining). On the basis of a 300-day work year, using coal requirements as given by A. C. Fieldner (27), and accepting $5 per ton-year as the investment required for everything, including the houses for workmen and railroad spurs, coal mines for hydrogenation plants to produce 100,000 bbl of gasoline daily would require an investment of approximately 150 million dollars for subbituminous coal and 195 million dollars for lignite.

It would seem therefore that the investment required for coal-hydrogenation plants per barrel of daily gasoline (including mining operations) would approximate $6,500 to $12,200; this figure is more than three times the average estimated amount required for gasoline-production and -refining facilities (this figure probably falls somewhere between $1,500 and $3,000) (23).

Fischer-Tropsch Synthesis from Coal

Discussion of Data. The Fischer-Tropsch process from coal involves two steps, (*a*) the gasification of any kind of coal or lignite and (*b*) the catalytic conversion of the synthesis gas to petroleum products. The yield of gasoline from bituminous coal would be about 2.3 bbl per ton and that from subbituminous about 1.7 bbl; the yield from lignite would be somewhat lower. Recent cost estimates range from 11.4 to 16.6 cents per gallon. However, it has been said that costs might run as low as 8 or 9 cents per gallon.

Man-power requirements for operation and mining per barrel of synthetic gasoline would be about the same order of magnitude as present man-power requirements for petroleum, or at least less than twice as high; they would be less than for coal hydrogenation.

It is believed that steel requirements for the construction of Fischer-Tropsch plants of the latest design might not be much higher than those for conventional petroleum refineries.

It has been recently estimated that Fischer-Tropsch plants using continuous coal-gasification methods require an investment of $8,500 per barrel of gasoline daily. Investment costs for plants using conventional coking methods were estimated, under 1943 economic conditions, as high as $7,600 per daily barrel; in any case mining investment might add about $750 and supplementary refining perhaps another $1,200 to $1,300 (23).

In combination with modern refining processes, the Fischer-Tropsch process appears to be quite flexible and can be used to produce a variety of high-quality products. The straight-run Fischer-Tropsch gasoline fraction, constituting about 85 per cent of the total, has an octane number of about 75 or, with 3 cc of lead, above 90.

The primary products contain up to 15 per cent of high-quality high-cetane-number diesel oil. This material can be blended with 60 to 70 per cent of low-cetane-number petroleum oils to produce a 50- to 60-cetane-number diesel fuel. By mild cracking of Fischer-Tropsch wax, it is also possible to produce a diesel-fuel fraction of about 85-cetane number.

Excellent lubricating oils probably can be obtained from the Fischer-Tropsch primary products, either by polymerization of high-boiling olefins or chlorination and alkylation of suitable paraffin fractions. For maximum lubricating-oil production, the C_3-C_4 fraction together with the cracked product boiling at about 150°C can be made to produce a 50 per cent yield of finished lubricating oil and a 30 per cent yield of motor-fuel stock.

The primary wax, amounting to 10 to 20 per cent, can be converted into waxes of various melting points. A 195°F-melting-point wax was being produced commercially in Germany before the war, and waxes of even higher melting points can be made.

Fischer-Tropsch products are too high grade to be used for heavy-fuel purposes.

Oil Yields. According to Dr. A. C. Fieldner of the Bureau of Mines (7, p. 172) and Bruce K. Brown, Vice-President, Standard

Oil Company of Indiana (7, p. 108), approximately 0.70 ton of bituminous coal is required to yield the coke needed per barrel of Fischer-Tropsch motor fuel and to provide the power, steam, etc., needed for the process; this figure checks closely with estimates made by others. Thus the yield of gasoline per ton of bituminous coal used in the older form of Fischer-Tropsch synthesis would be approximately 1.43 bbl.

Abroad, the synthesis gas used in the second step of the process has sometimes been made by gasifying lignite, subbituminous coal, and other varieties of coal (instead of coke) in continuous generators. Although these processes do represent improvement over the intermittent type of process that has been widely used in the United States for water-gas manufacture, it is believed that further improvements can be made in continuous gasification methods. From a technological and economic standpoint, the main step to be worked out for the Fischer-Tropsch synthesis from coal is the development of improved methods of making synthesis gas. Considerable work along this line is now being carried out in this country. The fact that this work is highly confidential probably accounts for the variance in yield data for continuous gasification which has appeared in the literature. For example, data published in 1947 (10) indicate a yield of 2.38 bbl of gasoline per ton of "coal," whereas more recent data (39) indicate a yield of only 1.96 bbl. Using continuous gasification of subbituminous coal, it is said (23) that a yield of 2.3 bbl of gasoline per ton of coal is obtainable; for subbituminous coal the yield is 1.7 bbl of gasoline. The yield from lignite would be still lower, but so might be the cost.

As regards primary products of Fischer-Tropsch synthesis, Dr. A. C. Fieldner (7, p. 172) states that 4 to 4½ tons of coke (5 to 6 tons of bituminous coal being required to yield the coke) are required to yield 1 ton of primary products. Assuming that the specific gravity of the average crude is about 0.8 (51, p. 174), it would seem that about 1.2 to 1.5 bbl of primary products are obtained per ton of bituminous coal used in this process for all purposes. When continuous gasification is used, a much higher yield may be anticipated—perhaps as high as 2.6 bbl. Data which would indicate yields of 2.2 to 2.76 bbl of liquid products per ton of "coal" have appeared in the recent literature (10, 39). Yields for subbituminous coal and lignite would be somewhat lower.

Costs of Production. Robert P. Russell (7, p. 39) stated in 1943 that a Fischer-Tropsch process of the coking type but of European design, using bituminous coal at $2.75 per ton, would yield gasoline costing 19.2 cents per gallon, including depreciation (which amounts to 4.5 cents per gallon in his figures). Fred Denig (7, pp. 242–246) estimated that the cost of Fischer-Tropsch gasoline from coke (from bituminous coal) would be 24.4 cents per gallon and that the cost would be 18.2 cents per gallon from coke from subbituminous coal. All these estimates are the results of detailed calculations but deal with the older European designs. It was stated in 1944 (23) that costs actually might be as low as 8 or 9 cents per gallon for plants using continuous gasification of subbituminous coal and lignite. E. V. Murphree (38) estimated in 1946 that gasoline produced in a 42-million-dollar plant with a daily capacity of 9,000 bbl of gasoline, 1,800 bbl of gas oil, and slightly under 40,000,000 cu ft of around 1000-Btu gas would cost "roughly" 7.25 cents per gallon. Mr Murphree's estimate was based on coal at $2.50 per ton and included a credit of 25 cents per 1,000 cu ft of gas and "suitable" credits for the gas oil and certain chemical by-products. Changing price levels are reflected in an estimate made by Mr. Murphree in 1948 (39). According to this estimate, the total cost of gasoline for maximum gasoline production, including 5 per cent amortization and 10 per cent return on both mining and manufacturing investments and based on coal at $3.20 per ton, would be 16.6 cents per gallon. This cost includes 3.9 cents for coal and 12.7 cents for manufacturing less credits. An increase of $1 per ton in the price of coal would add 1.2 cents per gallon to the total cost. Ten per cent capital charge on the manufacturing and mining investment was given as 5.6 cents per gallon. Mr. Murphree said his data were for a plant located in the East and that up to 1.9 cents per gallon might be added to the total cost if complete housing would be required. Another 1948 estimate reported by R. C. Alden and A. Clark (49) gave a gasoline cost of 11.4 to 16.4 cents per gallon.

It is still too early to say what effect the possible use of underground gasification of coal would have on either production costs or man-power requirements. However, experiments now underway may yield results of economic significance and therefore are worthy of mention.

Man-power Requirements. Based on a yield of 1.43 and 2.3

bbl of gasoline per ton of bituminous coal, depending upon the process for producing synthesis gas, between 43,500 and 70,000 tons would be required for a daily production of 100,000 bbl of gasoline. In 1944, when production of bituminous coal averaged 5.67 tons per man-day, this gasoline production would have required a mining man power of 7,670 to 12,340 men. In terms of 100,000 bbl per day of primary products instead of gasoline, only about 6,800 to 10,400 men would be required. For subbituminous coal for the modern process, approximately 10,370 men would be required to mine the coal needed for the daily production of 100,000 bbl of gasoline. Average production of lignite in 1944 was 12.95 tons per man-day (41). Yields from lignite are not at hand, but it has been assumed that man-power requirements for mining would be of the same order of magnitude as for the other ranks of coal (51).

Based on data (23) to the effect that one German plant producing 35,000 tons per year of crude oil (from which 25,000 tons of gasoline is obtained) has a staff of 230 men and an estimate that the crew could be halved for large-scale plants (this plant producing only 1,000 bbl per day), the production of 100,000 bbl of crude oil daily would require operating man power of less than 11,500 men, while the production of 100,000 bbl of gasoline daily would require a staff of approximately 16,400 men. Since it is generally known that Fischer-Tropsch synthesis requires less man power than coal hydrogenation, these figures are quite high and probably can be taken as upper limits. Joseph Pursglove, Jr., has estimated that a "commercial gasification and liquefaction plant using 20,000 tons of coal daily could create as many as 6,500 steady jobs . . ." (12). These figures would indicate a man-power requirement for the production of 100,000 bbl of gasoline daily (based on 43,500 tons of coal) of about 14,150 men.

Compared with the production of gasoline from petroleum, therefore, it would seem that the production of Fischer-Tropsch gasoline from coal (including coal mining) would have man-power requirements equivalent to the preparation of gasoline from petroleum (including production).

Steel Requirements. Various estimates have been presented as to the amounts of steel which would be required for the construction of plants to produce gasoline by Fischer-Tropsch synthesis. These estimates vary from 8.9 to 14.3 tons per daily barrel of gasoline; hence plants to produce 100,000 bbl of synthetic gasoline daily would require 890,000 to 1,430,000 tons of steel. These estimates include refining accessories, which, however, constitute only about 3 per cent of requirements. Robert P. Russell (7, pp. 38, 57) presented the lower estimate, while Fred Denig (7, pp. 246, 247) and Dr. A. C. Fieldner (7, p. 175) agreed closely as to the higher figure.

Modern plants using continuous gasification require less steel since the production and use of coke are avoided. E. V. Murphree made the lowest estimate that has appeared in the recent literature (39). According to Murphree, 5.2 tons of steel is required for each daily barrel of gasoline. It is believed (23) that steel requirements might eventually be of the same order of magnitude as those for gasoline production from petroleum.

Investment Required. According to Robert P. Russell (7, p. 36), the investment required for plants to produce 100,000 bbl of Fischer-Tropsch gasoline daily from coal (according to European design) would be approximately 760 million dollars. Fred Denig (7, p. 243) presented figures which yield an estimate of 618 million dollars (for prewar economic conditions, as are all his estimates). Bruce K. Brown (7, p. 111) gave figures which would yield an estimate of 1,000 million to 1,667 million dollars.

E. V. Murphree recently estimated an investment requirement of $7,600 per daily barrel for maximum middle-distillate yield and $8,500 for maximum gasoline yield (39). It has been roughly estimated (51, p. 178) that, for plants of future design, the figure might *ultimately* be as low as 100 to 200 million dollars per 100,000 bbl of gasoline daily—considerably less than the corresponding figure for coal-hydrogenation plants.

Taking 2 bbl per ton of coal as a rough estimate for modern plants and $5 per ton-year as a rule-of-thumb investment figure for coal mining, the production of 100,000 bbl of gasoline per day would require an investment in coal-mining facilities of about 75 million dollars for a 300-day working year. Much less would be required for strip mining.

It may therefore be seen that total investment requirements may be as low as $1,750 to $2,750 per daily barrel of gasoline, considerably less than those for coal hydrogenation and possibly of the order of magnitude of those required for gasoline production from petroleum.

Coal Carbonization

The consensus is that neither low- nor high-temperature intermittent carbonization of coal can be deliberately used as a method for producing very large quantities of synthetic liquid fuels. This opinion results from the fact that yields per ton are low, and vast amounts of coke are produced. Such coke is a very valuable smokeless fuel, it is true, and it is probable that low-temperature carbonization processes can yield liquid fuels at lower costs than by the hydrogenation of coal when markets for this coke can be found. There has been some discussion of linking low-temperature carbonization with Fischer-Tropsch synthesis to make use of the coke, but modern coal-gasification processes would seem to be much preferred. Recent developments in continuous carbonization may alter this picture.

A. C. Fieldner has presented a clear analysis of low-temperature carbonization (7, pp. 168–170). His figures show that "the average yield of gasoline that might be made per ton of high-volatile *A* bituminous coal carbonized without hydrogenation would be about 10 gal; and utilization of the same amount of coal in direct hydrogenation without carbonization would yield about 60 gal of gasoline. It is seen therefore that hydrogenation produces six times as much gasoline as low-temperature carbonization, and it does not depend on the marketing of smokeless solid fuel as the principal product."

George W. Carter of the University of Utah (7, pp. 353–356) has estimated that a low-temperature carbonization plant with modern oil-cracking facilities would cost on the order of $4,000 per barrel of gasoline daily (for a plant to produce 1,000 bbl of gasoline per day). Only 6 gal of better than 70-octane-number gasoline would be produced per ton of coal, along with 0.67 ton of smokeless fuel and 10 gal of phenols. The proposed process would be even less efficient than first appears, for it is proposed to produce the 6 gal of gasoline by cracking 15 gal of the neutral tar to coke. Carter states that the cost of coal carbonization would be $2.50 per ton of coal, figuring the cost of coal as $1.55 per ton. Allowing a value of $4.25 per ton of smokeless fuel produced and 94 cents per barrel of oil at the plant, and removing 40 per cent of the tar in the form of phenols, Carter estimates that the 6 gal of gasoline produced by cracking would cost about 10 cents per gallon. A gallon of benzol scrubbed from the carbonization gases raises the total motor-fuel yield to 7 gal per ton of coal. These yields are below the figures given by Fieldner.

I. C. Karrick (7, pp. 334–340) also has presented data on the subject. He shows much higher oil yields for many Rocky Mountain coals, and his estimates would yield very low gasoline-production costs. Frank Mueller, President of the American Lurgi Corporation (7, p. 145), Walter H. Wheeler, a consulting engineer (7, p. 155), and K. L. Storrs, President of the Coal Logs Company (7, p. 387), have also presented data on the subject.

Without going into the necessary calculations it is clear

1. That oil and gasoline yields are much lower than for other processes
2. That man-power requirements would be staggering for use on any large scale (unless the coke were used for Fischer-Tropsch synthesis, which would raise the cost of coal-carbonization fuels by lowering the by-product credits)
3. That costs per gallon of gasoline might be lower than for the hydrogenation of coal under favorable circumstances
4. That the investment per daily barrel of gasoline would be on the same order of magnitude as for coal hydrogenation, or perhaps a little lower

Oil Shale

An oil shale is a shale which contains little or no liquid oil or hydrocarbons that can be removed by ether, chloroform, or carbon tetrachloride (under normal conditions of treatment) but from which larger quantities of oil can be obtained by destructive distillation. This broad definition describes not only the deposits which have been classed as oil shale in publications which have described the rocks from which liquid oil to supplement petroleum may be secured but also countless billions of tons of shale from which traces of 3 to 4 gal of oil per ton of shale can be recovered. Therefore, the distinction between what may be considered a supplementary reserve and that which will fall within the technical definition of an oil shale is economic.

Factors that Determine Whether or Not a Given Deposit May at Some Future Date Become a Supplementary Reserve.

1. Richness—the amount of liquid hydrocarbon which may be recovered from a unit of shale.

2. The cost of mining a unit of this oil shale. This factor depends on the mechanical operation of digging and loading the rock, its accessibility, the method which must be employed in mining, the availability of an adequate water supply to permit effective mining operations, the cost involved in disposing of the spent shale or waste, and other factors.

3. The cost of distilling a unit of this oil shale.

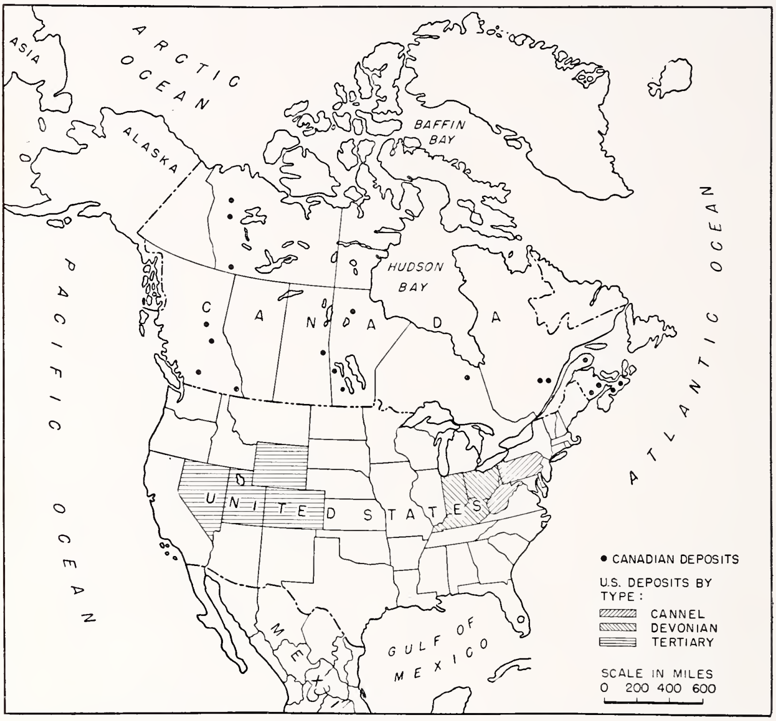

FIG. 55. Location of North American oil-shale deposits.

4. The products which may be secured from the oil recovered by distillation.

5. The location of the deposit with relation to markets. The costs of operation that can be borne by any deposit of oil shale will be determined by the cost of hydrocarbon products from other sources of supply. Oil shale can be worked wherever and whenever the cost of securing hydrocarbon products from it is no greater than the cost of securing them from other sources. Thus the oil

shales of Scotland were profitably exploited prior to the time when crude petroleum in great quantities was imported by England from the oil fields of the United States, South America, and the Near East.

If the cost of transporting the product to market is very low, high costs of mining and distilling or low yields per ton may be compensated for to some extent by a negligible cost of distributing the finished product.

6. The size of the deposit. The value of the liquid hydrocarbon that can be secured by mining and distilling the shale in a given deposit must exceed the original investment and the estimated operating costs. This precludes working very small deposits, even though the shale in such deposits may be phenomenally rich.

Geographic Distribution of Oil Shales in the United States and Canada. The geographic distribution of the deposits of oil shale that now seem most important is shown on the accompanying map (Fig. 55). The map does not indicate areas known to be underlain by oil shale at depths ranging from several hundred to a few thousand feet, nor does it outline large areas where oil shales that will yield only a few gallons of oil per ton are known to exist. Known Canadian deposits are indicated by dots; the extent of these deposits is not known.

Geologic Occurrence of Oil Shale in the United States and Canada. Shales which will yield oil on distillation are found in rocks belonging to each of the major geologic periods. The richest and most extensive deposits, and the ones that are therefore most nearly commercial, are in rocks belonging to the Devonian, Mississippian, and Tertiary periods. These shales are the bottom sediments that accumulated below extensive bodies of shallow water, which might be either fresh or saline. In these shallow-water bodies flourished a remarkable growth of water plants, dominantly algae, some of them similar to the algae that are popularly but incorrectly called "slimes" or "mosses," which may today be observed growing beneath the water surface in streams, pools, and lakes. The waxy, fatty, and resinous parts of these water plants, together with organic material that might be blown into the water bodies and the remains of insects and in some instances of fish, all settled to the bottom along with the clay and very fine sand that was washed into the water bodies and was fine enough to remain suspended for a period in the comparatively quiet water and be widely distributed throughout its expanse. Judging from the thickness of the accumulated oil shales, some of these lakes must have persisted for hundreds of thousands of years before they were either dried up by change of climate or terminated by earth movements which destroyed the barriers which had permitted the water to accumulate.

The richest oil shales are those where the bulk of the rock comprises the remains of the algae and other plants, with a comparatively small per cent of mineral matter, which represents the clay and fine sand in the water bodies beneath which the shale accumulated. The leaner shales contain a comparatively high percentage of mineral matter, with the remains of plants, insects, and other organisms comprising a minor part of the rock as a whole.

There is no sharp line between oil shales and the types of coal known as cannel coals and Bogheads. The cannel and Boghead coals might be called ultrarich oil shales, since they are composed almost 100 per cent of the products that resulted from the decomposition of water plants that grew in bodies of water so protected that practically no mud or sand was mixed with the organic matter.

Procedure by Which Tonnage of Oil Shale Has Been Estimated. All past estimates of the tonnage of oil shale in the United States and Canada have been approximations based on assumptions that may or may not be valid. They do not accurately tell how much oil shale actually is available or how much liquid hydrocarbon can be obtained from it. They do serve, however, to leave no doubt that the total tonnage of oil shale is very large and that it contains far more oil than has been produced from the oil fields of the world.

The most dependable of the early studies seem to be those by Dean E. Winchester, especially one on the "Oil Shale of the Rocky Mountain Region," published in 1923 by the U.S. Geological Survey, and a later report on the entire country, published in 1928. Most of the estimates of the oil shale in other parts of the United States have been based on even less work and involve more questionable approximations than do the estimates by Winchester in the first report. The extent to which approximations may affect these estimates is well illustrated by two other estimates of the oil that may be recovered from the black shales of Kentucky and adjoining states. One author, writing in 1927, estimated that there were enough shales which would yield 13 gal of oil per ton and easily available for mining to yield 60 billion barrels. Another author, writing in 1928 and assuming a yield of 10 gal per ton of shale, estimated that the minable deposits might be expected to yield only about 18 billion barrels. At the moment this difference is unimportant, since existing technology will not permit oil from shales yielding only 10 to 13 gal per ton to compete with petroleum products.

The procedure following by Winchester in the Rocky Mountain region was to determine the approximate outline and extent of the areas where oil shale occurred at or close below the surface. The thicknesses of exposed beds of oil shale were measured at selected points. In this rugged region thousands of feet of strata are exposed in deep canyons and on the abrupt slopes of mesas and mountains, so that there were many localities where accurate measurements could be made and samples of the exposed oil shale could be secured.

It was assumed that the measurements thus made were representative of the entire deposit or that from them increases or decreases in the thickness of layers of oil shale could be estimated. Many samples collected from many beds of oil shale were distilled to determine the yield of liquid hydrocarbon. Fragments of these same samples were then heated in glass test tubes, and observers were trained to correlate the test-tube results with those obtained by distillation. Subsequently, by using the quick test-tube method the approximate yield of hundreds of additional samples was determined. It was assumed that the beds that were sampled would be uniform in yield of liquid hydrocarbons or that by averaging the yields secured by sampling the same bed at widely separated points the approximate yield of the stratum as a whole could be estimated.

It is known that the estimates determined by these approximations were low, both because Winchester depended in great part on samples taken from beds long exposed to the weather and now known to contain about 13 per cent less oil than do fresh samples from drifts, tunnels, or cores, and because recent sampling in Colorado has revealed reserves richer than those of which Winchester was aware (19*a*).

The figures in all published estimates depend on the factors which the estimator believed would determine the minability of the deposits. Whether or not a deposit can be mined depends on the cost of the mining operation and on the value of the material which is mined. Present-day technology is lowering costs; a scarcity of natural petroleum would naturally increase the value of shales. These factors may ultimately make many of the existing estimates appear ultraconservative.

No existing estimate gives any value to the great tonnage of oil shales that occur at depths of a few hundred to a few thousand feet below the surface. For example, much of eastern Oklahoma and eastern Kansas are underlain by the Kinderhook formation, which corresponds in age and characteristics to some of the oil shales that crop out in Kentucky.

Availability of the Supplementary Reserves of Oil Shale. No significant part of these reserves are available at present, nor will they be commercially available as long as consumers of petroleum products can satisfy their needs at a lower cost than these needs can be filled by products from oil shales.

It is a fallacy to think of all or even most of domestic oil shales as available. For example, if all the oil shales of western Colorado, eastern Utah, and southwestern Wyoming were mined, a desert 200 miles long and 150 miles wide would be created that would surpass in complete desolation anything the world has ever seen. The rivers that drain this area would be loaded not only with the fine-grained material from the expanse of spent shale but also with the chemicals that had been rendered soluble by distilling this shale. This would affect regions as far away as the Imperial Valley of California.

Similar limitations will affect the utilizing of oil-shale deposits in other parts of the United States. Oil shale that underlies communities or valuable surface lands cannot be extracted under existing conditions except by mining methods that will completely protect the surface. There must be provision for the disposal of the spent shale, and pollution of streams and ground water by chemicals leached from the shale must be prevented.

Some of the oil shale of the Rocky Mountains will be economically unavailable for an indefinite time because of the great difficulty and expense that would be incident to developing roads and water supply to make available oil-shale deposits in remote and rugged areas.

Discussion of Data. Research now being undertaken by the Bureau of Mines under provisions of the Synthetic Liquid Fuels Act passed by Congress in 1944, is contributing technological developments in mining, retorting, and refining for the production of petroleum substitutes from oil shale. Operation of shale-oil mines and a demonstration retorting plant near Rifle, Colo., as well as research on a smaller scale at laboratories at Laramie, Wyo., are providing data which give some indication of the potential possibilities of a shale-oil industry. Also of interest in connection with the Bureau's research at Rifle is sampling of the shale formation, incidental to planning of the mines. This sampling had led to some revision of estimates of oil-shale reserves.

The proportion of oil-shale reserves which might be considered a primary source of substitute fuel depends largely upon geologic factors and location. Recent core drilling in the Rifle area has indicated that there may be as much as 200 billion barrels of recoverable crude in Colorado alone (47), which would yield perhaps 100 billion barrels of gasoline.

The mining of oil shale is said to be somewhat cheaper per ton than the mining of average coal, but the yield of crude oil per ton of oil shale is only about one-half (for shale assaying about 20 gal. per ton). Even so, the investment cost of oil-shale mining has been figured at only about $1.42 per barrel of crude per year, compared with a possible mining investment of $5 per barrel of gasoline by coal hydrogenation and $2.50 for Fischer-Tropsch.

Crude shale oil is produced from oil shale by retorting. The cost of this crude is made up of mining and retorting costs, and estimates have been as low as $1.75 to $2 per barrel. Shale oil, however, is a low-grade crude, so that the cost of converting this crude to gasoline might be comparable with the cost of processing a heavy natural petroleum.

Man power for mining and operation to obtain crude oil would be somewhat higher than man-power requirements for the production of petroleum. Additional man power would be required for refining the crude, but requirements may not be much greater than for petroleum refining.

Steel requirements would not be much higher than for conventional petroleum refineries.

The investment required for retorting has been figured at about $700 to $1,020 per barrel of crude per day. To this should be added about $190 to $427 for mining and more for refining the crude. Per daily barrel of gasoline, the investment would total about $3,100 to $8,400. The lower figures apply for richer shales, the higher figures for leaner shales. The investment for gasoline varies according to the process employed in refining and the inclusion or exclusion of investment for transportation from the mine site to the refinery.

By cracking to a heavy residuum it is possible to obtain gasoline yields from shale oil ranging from 35 to 55 per cent, while cracking to coke results in 50 to 60 per cent yields. Octane numbers [American Society for Testing Materials (ASTM)] range from 55 to 75, depending on the shale oil and the cracking process. Higher yields (about 80 weight per cent) of gasoline (65- to 67-octane number) can be produced by hydrogenation. These hydrogenated gasolines have high lead susceptibilities and with 3 cc of lead may have octane numbers in the range of 83 to 85.

By hydrogenation may also be produced diesel fuel, lubricating oil, and paraffin-wax fractions in yields of almost 100 weight per cent. The hydrogenated diesel fractions are reported to have cetane numbers in the range of 60 to 75, and the lubricanting oils are said to resemble Pennsylvania machine oils. It appears that hydrogenation is the most successful method of refining shale oil, although possibly not the cheapest method for gasoline production.

As in the case of the products from coal hydrogenation, shale oil is potentially an important source of organic chemicals. By-products include nitrogen bases, present to the extent of 2 to 5 per cent, and phenols, which may be present in even larger amounts.

Reserves. Oil-shale reserves of the United States are now known to exceed the total of 400 billion tons estimated several years ago (52). These reserves were said to contain some 100 billion barrels of recoverable oil. Recent sampling in Colorado incidental to selection of a mine site by the Bureau of Mines shows earlier estimates to have been too conservative (13). The need for a more modern survey has been discussed in some quarters (7, p. 127). W. E. Wrather has testified (7, p. 99) that since Winchester's survey large additional Ordovician oil shales have been discovered in Nevada. It is known that oil-shale deposits also exist in Tennessee, Alabama, Montana, and other states, but the extent of these deposits is not known exactly, nor are they as rich in oil as those listed in Table 3.

Table 3 is adapted from Winchester's report. As can be seen, he subdivided the oil shales into three classes: Tertiary oil shales of the Rocky Mountain region, Devonian black shales of the Eastern states, and the cannel shales of the Eastern states. As A. J. Kraemer, senior refining engineer of the Bureau of Mines, has stated (7, pp. 313, 314), Winchester based his recoverable-oil estimates on varying factors of market accessibility, mining costs, mining losses, etc., for each of the three classes; his estimates, incidentally, were made at a time when average well oil was valued at $5 to $6 per barrel and hence in some cases may be too high.

TABLE 3. ESTIMATE OF OIL RECOVERABLE FROM OIL SHALES*
(Thousands of barrels of 42 U.S. gal)

State	Total oil	Recoverable oil
Tertiary oil shales:		
Colorado	79,625,998	47,625,598
Nevada	6,039	3,623
Utah	47,800,000	25,680,000
Wyoming	3,044,000	1,826,400
Total Tertiary oil shales†	125,476,037	75,335,721
Devonian black shales:		
Indiana	7,680,000	6,912,000
Kentucky	10,978,500	9,880,704
Total Devonian black shales‡	18,658,560	16,792,704
Cannel shales:		
Pennsylvania	13,800	8,280
West Virginia	13,800	8,280
Total canned shales	27,600	16,560
Grand total	144,162,197	92,144,985

* Source: Dean E. Winchester, "The Oil Possibilities of the Oil Shales of the United States," Appendix 1, Report 2 of the Federal Oil Conservation Board to the President of the United States, January, 1928, Washington, D.C., 1928.

† This estimate does not include small amounts of oil shale known or reported in the states of California, Montana, and Oregon.

‡ No estimate is made for the states of Ohio and Tennessee, although it is recognized that undoubtedly there are areas of minable oil shale in these states.

For the Tertiary oil shales, because of the present remoteness from markets and "the probable added cost of mining due to the possible necessity of using underground mining methods," Winchester stated that "no (Tertiary) oil shale was considered minable if it was less than 1 ft thick or if it would yield less than 15 gal of oil to the ton, or less than 3,000 bbl of shale oil per acre of shale land." As Kraemer states, this means that "a shale stratum 4 ft thick and yielding 15 gal of oil per ton of shale, or a stratum 1 ft thick yielding 60 gal of oil per ton, in minable" (7, p. 313). To be ultraconservative, Winchester estimated his recoverable oil on the basis that only 60 per cent of such shale would reach the retorts. He actually believed it not at all impossible that 95 per cent of the minable shale could be used, and Kraemer states that "in the best operations, using the most economic, large-scale mining methods, the percentage (60) doubtless would be larger."

A large percentage of the Devonian black shales of the eastern United States are said to lie near the surface and to be minable by open-cut methods. They lie near markets, supplies, and labor, "thus enhancing their value and making it probable that thin strata and lean shales can be worked" (7, p. 313). Winchester stated in his estimate that "no (Devonian black) shale was considered minable it it was less than 1 ft thick or if it would yield less than 10 gal of oil to the ton of shale or less than 2,000 bbl of oil per acre." As Kraemer states, "only oil shale that might be mined by open-cut steam-shovel methods was considered in making the estimates; consequently, it was estimated that 90 per cent of the shale in the ground would reach the retorts for treatment."

The cannel shales of the coal measures, which lie in Pennsylvania, West Virginia, and Missouri, are said to be high-ash cannel coals. Kraemer states that the deposits are "characteristically lenticular and local" and that Winchester estimated that not more than 60 per cent of the cannel shale in the ground would reach the retorts.

From these figures it can be seen that the oil-shale regions of Colorado, Utah, and Wyoming, far from the present major sources of petroleum, contain the bulk of recoverable shale oils as well as the bulk of total shale oils. Recent core drillings in Colorado combined with other samplings made by the U.S. Bureau of Mines indicate that the preponderance of shales concentrated in these states is even greater than Winchester's report indicates. W. C. Schroeder states that the reserves in Colorado alone amount to as much as 200 billion barrels of recoverable oil based on a shale assaying, as in the case of Winchester's estimate, 15 gal per ton (47).

"Perhaps the best recent analysis of the situation was that made by Carl Belser of the Bureau of Mines in May, 1947, based on published reports of the U.S. Geological Survey, the results of core drilling and sampling by the Bureau of Mines, the drill cuttings from the General Petroleum well, a recent unpublished report by the Geological Survey on the geology of Naval Oil-shale Reserves No. 1 and No. 3, and information supplied by geologists of private companies. His study is limited to the Green River formation, which is believed to contain most of the oil shale of the United States. He concludes that about 345 billion barrels of shale oil are represented by the deposits of oil shale in existence in Colorado, Utah, and Wyoming—most of it in Colorado. He does not attempt to predict how much of this reserve contains enough oil to justify retorting, or how much is located in such a way as to be minable. He states: 'The oil content of at least 50 per cent of the Green River formation in Utah and 90 per cent in Wyoming is unknown. Only one sampled section is available for every 39 square miles of Green River formation in Colorado, 195 sq miles in Utah, and 1,150 sq miles in Wyoming.'

"The oil recoverable from oil shale varies from traces to 60 gal or more per ton. It costs just as much to mine shale yielding 1 gal per ton as that yielding 60 gal per ton. Furthermore, the retorting cost is almost independent of the oil yield. The oil yield is, therefore, one of the most important factors to determine the amount of oil shale which could be mined and retorted with reasonable economy. There are now not nearly enough data to estimate the size of our reserves of oil shale which would yield more than a given proportion of oil—say 30 gal per ton. Such data are being sought now by the Bureau of Mines and should eventually throw considerable light on the importance of our reserves of shale oil.

"The final picture, when it can be drawn, will take mining losses into account and will give the reserve as a table or a curve rather than as a number, for we could doubtless recover ten times as much shale oil if we were content to pay double the cost.

"Assuming that the 345 billion barrels of shale oil is 95 per cent of the United States total, we can say at this time that the *total* shale oil in the United States is about 365 billion barrels. This is a figure which should not be compared with petroleum estimates that assume recoverability under reasonably economic conditions. A considerable portion of the 365 billion barrels would probably not be recoverable except at fantastic costs. Perhaps 15 per cent of it could be recovered at about the price of mid-continent crude and perhaps 50 per cent of it at three or four times this cost. Any estimate higher than, say, 80 billion barrels would seem unjustified until we have more information" (18).

It is interesting to note that F. B. Plummer, University of Texas geologist, in a tabulation of oil-shale acreage "available for oil-shale extraction," assigns 2,700,000 such acres to Utah and only 900,000 acres to Colorado (44).

It is impossible to estimate Canadian oil-shale reserves from the literature; in fact A. A. Swinnerton of the Canadian Bureau of Mines stated in 1938 (4) that "sufficient development work has not taken place to determine the oil-shale reserves in even the most favorably situated deposits." A survey reported by the Minister of Mines to the Canadian House of Commons in 1943 showed the best area of New Brunswick to contain only 2 million tons of shale assaying 20 gal per ton (22). From what little is known, Canadian reserves do not appear at all comparable with those of the United States.

Oil Yields. Scottish shale-oil operations have long used shales with an oil yield of 22 to 24 gal per ton. "There are billions of tons of shales in the Colorado deposits (and elsewhere) which will yield double this amount of oil and 'vast quantities' that will yield from 50 to 60 gal per ton. In addition to these are immense tonnages which will equal the Scotch in oil content" (29). The Bureau of Mines experiments at Rulison, Colo., used shales with an assay value (including 10 per cent dilution) as low as 23.8 gal of oil per ton of shale and did not term these uneconomic (28). A. J. Kraemer (7, p. 299) stated that "deposits of sufficient size and richness to warrant utilization range in assay value from about 25 to 45 gal (0.595 to 1.07 bbl) of oil to the ton." Whether he meant this to include all United States shales is not clear.

One of the Bureau of Mines' recently opened mines near Rifle, Colo., is designed to mine shale of any richness between 5 and 80 gal per ton. There is no indication, however, that the poorer grade represents a shale suitable for commercial working (13, p. iv). The bulk of the shale that has been prepared for retorting at the Bureau's demonstration plant at Rifle yields approximately 30 gal per ton (13, p. 2). A tabulation of "minable oil-shale beds" at the Bureau's plant gives a shale assaying 16.68 gal per ton as the leanest and a shale assaying 61.98 gal per ton as the richest (13, p. 8). Elsewhere (19) it is reported that American shales assay 30 to 60 gal per ton, the weighted average being about 43. According to A. J. Kraemer and F. E. Buchan, shales yielding 10 gal per ton may be termed "of probable future commercial importance" (35).

It is obvious that the richest shales (when available in large deposits) will be used first for oil production, so that with the improvements in technology that are certain to occur it may eventually be practical to recover oil from shales whose oil contents are now considered too lean. It would seem fairly safe therefore to consider as relatively economic those appreciable deposits of oil shales whose oil content exceeds 20 bbl per ton. Retorting operations with N-T-U retorts have yielded 95 per cent of the oil in the shale being processed (43). It does not seem unreasonable to expect similar retorting efficiencies in a future shale-oil industry. On this basis, 220,000 tons of shale with an assay value of 20 gal to the ton would have to be mined per day to yield 100,000 bbl of oil per day. Only 177,000 tons of shale would be needed for shale with an oil-assay value of 25 bbl per ton and only 98,300 tons for shale with an oil-assay value of 45 gal per ton.

"Yields of gasoline (of 225 to 437°F—end point) of from 35.2 to 55.3 per cent have been obtained by cracking American, French, Australian, and Scottish shale oils to residuum at 414 to 449°C (1033 to 1096°F) and at pressures of 120 to 175 psi. The yields obtained depended upon the nature of the oil, the cracking conditions, and the quality of the residuum. Cracking to coke gave gasoline yields of 50 to 60 per cent" (52). A. J. Kraemer (7, p. 317) has stated that cracking to coke and gas (on the basis of 1929 technology) can yield 25 gal of gasoline (23 gal after treating) per barrel of crude shale oil (60 per cent) and that higher yields probably can be obtained by use of modern processes. Research on shale-oil refining is now proceeding rapidly. Developments to date indicate that gasoline obtained from shale oil by conventional refining methods would be of poor quality. Even mild hydrogenation yields an inferior product which would require further treatment. Destructive hydrogenation, on the other hand, is relatively expensive (36). Nevertheless, yields of gasoline from hydrogenation would probably be high; the Bureau of Mines assumes they would be 107.2 per cent on a volumetric basis (13, p. 44). With the specific gravity of the gasoline assumed to be about 0.71 and that of the crude shale oil to be about 0.931 [20.4°API, as has been reported (36)], this is equivalent to a yield of about 82 per cent by weight.

It is highly probable that shale oils would not be cracked completely to gasoline, as most of them contain varying percentages of the entire range of petroleum products, but, assuming that gasoline were the sole desired product and using the 60 per cent yield basis, some 366,000 tons of shale with an oil-assay value of 20 gal per ton would be required to yield 100,000 bbl of gasoline per day. For oil-assay values of 25 bbl and 45 bbl per ton, respectively, 296,000 and 164,000 tons of shale would be required daily for the same gasoline production.

It is not certain that hydrogenation would be selected as the method best suited to refining shale oil, nor is it even certain that gasoline would be the principal shale-oil, refinery product. However, if shale oil were hydrogenated to gasoline, on the basis of 82 per cent yields, some 270,000 tons of shale assaying 20 gal per ton would have to be mined to provide for production of 100,000 bbl of gasoline daily. In the case of shales assaying 25 and 45 gal per ton, corresponding raw material requirements would be 216,000 and 119,800 tons of shale, respectively.

Costs of Production. The available cost data for shale oil are conflicting. Mining costs are still controversial. According to the Bureau of Mines, a mine producing 15,000 tons of shale per day would require a total expenditure of about $10,500 per day, including $5,500 for labor (344 men at $2 per man-hour), $3,500 for supplies, and $1,500 for depreciation (13, p. 12). These figures indicate a mining cost of 70 cents per ton of shale. On a yield basis of 0.7 bbl of oil per ton of shale and a retorting efficiency of 95 per cent, the mining cost per barrel of oil produced would be $1.05. W. C. Schroeder has stated that the Bureau's mine at Rifle is already producing 25 tons per man-day and is expected to attain an output of 40 to 50 tons per man-day at a mining cost of 50 to to 60 cents per ton during the current year (47). It is the opinion of some industrial mining experts, however, that mining costs cannot be brought under $1 per ton.

Cost of crushing 30-gal shale to 3.5-in. size at Rifle is averaging 19 cents per ton, but an average cost of 16 cents was attained during one month. It is expected that lower costs would apply for larger installations than those in use at present and that continuous operation should cut costs still further (13, pp. 2, 16).

Estimates of costs of retorting are still undependable. The lowest cost so far attained by the Bureau of Mines is 9.6 cents per gallon of crude shale oil produced. The expected cost for the near future, however, is 5 cents per gallon. Both estimates are based on insufficient data (13, p. 20).

Total cost of producing crude shale oil can be computed from the data thus far discussed. Mining costs are estimated at $1 per ton, or, on the basis of 30 gal per ton shale, $1.40 per barrel. Crushing at 16 to 19 cents per ton would add another 22.4 to 26.6 cents per barrel, and retorting at 5 to 9.6 cents per gallon would add $2.10 to $4.03 per barrel. If retorting efficiencies are assumed to be about 95 per cent, preretorting costs would amount to $1.70 to $1.75 per barrel and the total cost of producing a barrel of crude shale oil would be $3.80 to $5.80.

The figures presented above appear to be entirely out of line with other estimated costs of producing crude shale oil. A. J. Kraemer (7, pp. 315, 316) stated in 1943 that shale oil produced from Colorado shales would cost $1.75 to $2 per barrel (all costs on a 1942 basis). Extrapolating figures obtained in the literature and reported in (52), it would seem that other estimators (on less reliable data, perhaps) have made estimates ranging from $0.91 to $1.83 per barrel, with probable costs of the order of magnitude of the latter figure. L. C. Karrick, formerly of the Bureau of Mines, testified in 1943 (7, p. 334) that shale oil could be manufactured profitably for about 75 cents per barrel by use of underground treatment; no details were given to substantiate this estimates, Kraemer's, Karrick's, and those presented in reference (52), are based on technology known prior to 1929. According to a paper by W. C. Schroeder (47) published in 1948, $2.75 per barrel represents the upper limit of private industry's estimate, while one large company has set the figure as low as $1.75 per barrel. Bureau of Mines research indicates a cost of $2 to $2.50 per barrel. Previously presented costs of retorting and crushing are based on small-scale operations and would seem to be subject to substantial reductions so as to yield a less expensive crude as indicated by the cost estimates given by Schroeder.

In regard to gasoline costs, A. J. Kraemer (7, pp. 316, 317), using data from the Colorado experiments of the Bureau of Mines (prior to 1929) for cracking crude shale oil to coke, obtained estimates of 9.7 to 10.7 cents per gallon of finished gasoline. E. V. Murphree of Standard Oil Development Company recently testified before a House subcommittee that, for a plant designed for maximum gasoline output, the cost of producing gasoline would approximate 16.0 cents per gallon (16). Murphree's cost is based on shale mined and retorted in Colorado; the crude shale oil is transported to California by pipe line for refining. This would account in part, perhaps, for the discrepancy between Murphree's estimate and one made by the Bureau of Mines for gasoline production by liquid-phase hydrogenation, saturation vapor-phase hydrogenation, and splitting vapor-phase hydrogenation, all at 4,300 psi. The Bureau's hypothetical plant would produce 7.8 cents per gallon gasoline from $1.50 per barrel crude (coal for production of hydrogen and refinery energy at $4 per ton). The plant, designed to produce 20,000 bbl per day of shale oil with an assumed hydrogen consumption of 75 million cubic feet, would yield 121 per cent by volume of liquid products, 107.2 per cent gasoline, and 13.8 per cent liquefied petroleum gases, the latter being credited at 6 cents per gallon. For a crude costing $2 per barrel, gasoline produced in the same plant would cost 8.29 cents per gallon. These estimates allow 9 per cent for amortization and 9 per cent for indirect costs (13, p. 44).

Man-power Requirements. Operation of two oil-shale mines near Rifle, Colo., by the Bureau of Mines has recently disclosed a marked reduction in man-power requirements for mining operations. This has resulted from employment of methods adapted to the thick shale beds of the Colorado region. One of the mines is in effect an underground quarry where use of large-scale mechanized equipment in rooms 60 by 100 ft has brought about a production of 25 tons of shale per man-day. An increase to 40 to 50 tons per man-day is expected before the end of the current year (47; 13, pp. iv, 2). The Bureau estimates a mine to produce 15,000 tons of shale per day would require an over-all labor force of 344 men, equivalent to 44 tons per man-day (13, p. 12). Table 4 summarizes approximate man-power requirements for various outputs, accepting an estimate of 0.022 man per daily ton of shale (or about 45 tons per man-day) as a rough average.

No direct estimates of man power for crushing operations are as yet available. The government's installation at Rifle has a capacity, dependent on the particle size, ranging up to 80 tons per hour. This unit requires 2 men per shift, or 6 men per day, for continuous operation (13, p. 2). Based on these figures and disregarding crushing losses, the man-power requirement for crushing shale for the production of 100,000 bbl of crude shale oil per day would be about 690, 550, and 305 men for shales assaying 20, 25, and 45 gal per ton, respectively. Corresponding figures for the production of 100,000 bbl daily of gasoline by cracking (60 per cent yield) would be 1,150, 920, and 510 men. For hydrogenation (82 per cent yield) these figures would be 840, 675, and 375 men, respectively. It is considered that a much larger unit could be operated with the same man power. Therefore, these figures would be considerably higher than actual man-power requirements. Nevertheless, it is obvious that man-power requirements for crushing operations would constitute a relatively small portion of the total man power required for producing crude oil or gasoline from oil shale.

Research at the Bureau of Mines retorting plants as yet has not progressed sufficiently to allow estimation of the number of men required for retorting shale. Computations based on a monthly throughput of 1,000 tons attained in retorts manned by 3 men per shift at Rifle, with an assumed yield of 95 per cent, leads to the ridiculously high figures of about 59,800, 47,800, and 26,500 men for retorting shale to yield 100,000 bbl of crude daily from shale assaying 20, 25, and 45 gal per ton, respectively. On the same basis, man-power requirements for retorting for the production of 100,000 bbl daily of gasoline by cracking (60 per cent yield) would be 99,500, 79,500, and 44,200 men for 20-, 25-, and 45-gal shale. Corresponding figures for production by hydrogenation (82 per cent yield) would be 72,800, 58,300, and 32,400 men, respectively. It is believed that when a large bank of retorts equipped with the latest instruments, mechanical improvements, etc., is employed,

TABLE 4. APPROXIMATE MAN-POWER REQUIREMENTS FOR SHALE MINING

Type of production	*Men required*
For production of 100,000 bbl of crude shale oil daily:	
From shale assaying 20 gal per ton	4,900
From shale assaying 25 gal per ton	3,900
From shale assaying 45 gal per ton	2,200
For production of 100,000 bbl of gasoline daily (by cracking, 60 per cent yield):	
From shale assaying 20 gal per ton	8,200
From shale assaying 25 gal per ton	6,500
From shale assaying 45 gal per ton	3,600
For production of 100,000 bbl of gasoline daily (by hydrogenation, 82 per cent yield):	
From shale assaying 20 gal per ton	6,000
From shale assaying 25 gal per ton	4,800
From shale assaying 45 gal per ton	2,700

man-power requirements could be reduced to one-half or less of the current figures. Even so, the resulting estimates would appear too high. Assessment of man-power requirements for retorting, apparently, must await further research and development (13, pp. 3, 20).

Although the man-power requirement for retorting might eventually be comparable with that for petroleum production, it is obvious that total man-power requirements would definitely be larger than those for petroleum production and refining.

Steel Requirements. According to A. J. Kraemer (7, p. 295), 7,500 tons of steel is required for retorting plants to produce 5,750 bbl of crude shale oil per day from 10,000 tons of shale having an assay value of 25.4 gal of oil per ton, thus indicating a steel requirement of 1.3 tons of steel per barrel of oil. Warwick N. Downing (7, p. 295) has stated that steel requirements for mining operations would be negligible. On this basis the production of 100,000 bbl of crude shale oil from shale of this richness would require 130,000 tons of steel. It is obvious that less steel per barrel would be required for richer shales, since lower tonnages would have to be retorted per barrel.

Carrying these calculations a step further and assuming a gasoline yield of 60 per cent and that refining plants to produce gasoline would require 2.0 tons of steel per daily barrel of gasoline, the production of 100,000 bbl of gasoline daily would require plants containing 417,000 tons of steel for shale with an assay value of 25.4 gal per ton. E. V. Murphree recently estimated total steel requirements for maximum gasoline production would amount to 7.4 tons per daily barrel of gasoline. Murphree's estimate is based on shale assaying 30 gal per ton and includes the steel required for retorting the shale in Colorado and transporting the shale oil by pipe line to California, where it is hydrogenated and then processed into gasoline by conventional refining techniques. This estimate would indicate a total steel requirement of 740,000 tons for the production of 100,000 bbl of gasoline daily. According to Murphree's data, total steel requirements for gasoline produced from oil shale are essentially equal to those for production for natural petroleum (39).

Investment Required. A. J. Kraemer (7, p. 316) has presented investment data for mining 6,250 tons per day and 10,000 tons per day of Colorado oil shales having assay values, respectively, of

35.4 and 23.8 gal per ton of shale. From his figures an investment for mining facilities of between $208 and $210 would be required per ton of shale mined daily (*i.e.*, investment costs per ton are almost identical regardless of shale richness). More recently the Bureau of Mines presented investment data for mining 15,000 tons per day of Colorado shales assaying about 0.7 bbl of oil per ton of shale. According to these data a cost of 1.1 million dollars for "surface facilities including roads, yard excavation, power and water-supply development, and buildings" plus an additional 1.8 million dollars for "equipment, including drilling carriages, electric shovels, haulage trucks, service trucks and vehicles, ventilation and air-compression equipment, and utilities" at 1947 prices would be equivalent to an investment of $193 per ton of shale mined per-day (13, p. 12). This estimate would indicate that to mine enough shale of an assay value of 20 gal per ton to yield 100,000 bbl of oil daily, an investment for mining facilities of approximately 42.7 million dollars would be required (based on 95 per cent retorting yields). For shales assaying 25 and 45 gal per ton, the investment for the production of 100,000 bbl of oil daily would be about $34,100,000 and $18,950,000, respectively. To produce 100,000 bbl of gasoline daily from 20, 25, and 45 gal per ton shale by cracking (60 per cent yield), the investment for mining facilities would run about 71.3 million, 56.9 million, and 31.7 million dollars, respectively. Corresponding figures for production by hydrogenation (82 per cent yield) are 52 million, 41.7 million, and 23.2 million dollars.

Unfortunately, no estimates based on recent data for retorting investment requirements are at hand. According to data presented by A. J. Kraemer (7, p. 316), it would seem that retorting facilities require an investment of $700 per daily barrel of oil when processing shales of an assay value of 35.4 gal of oil per ton are processed, and $1,020 for shales with an assay value of 23.8 gal per ton. Thus, retorting facilities to produce 100,000 bbl of crude shale oil per day would require an investment of the order of 70 million to 102 million dollars. Retorting facilities to produce the crude shale oil required for the production of 100,000 bbl of gasoline daily by cracking (60 per cent yield) would cost from 117 million dollars for the above shales. Corresponding figures for production by hydrogenation (82 per cent yield) would be 85 million to 125 million dollars.

The data on investments quoted from A. J. Kraemer so far have come from Table 5 (7, p. 316). The capital-investment figures of $1,140 to $1,160 and $1,640 to $1,670 per barrel of shale oil daily are good median figures to those reported in the literature (52); such estimates range from $375 to $3,000 per daily barrel of shale oil (the higher estimates being the oldest). Based on the data presented in Table 5, it would seem that an investment of 114 million to 167 million dollars would be required for the production of 100,000 bbl of crude shale oil per day. Considering current economic conditions, it would appear that W. C. Schroeder's recent estimate (47) of $2,000 per daily barrel of crude shale oil compares favorably with the estimates given above. It would seem, therefore, that an investment from perhaps as low as 114 million dollars up to 200 million dollars would be required for the production of 100,000 bbl of crude shale oil per day.

TABLE 5. COST OF AN OIL-SHALE PLANT OF COMMERCIAL SIZE*

Size of operation:		
Shale to be retorted, tons per day	6,250	10,000
Oil to be produced, bbl per day	5,000	5,380
Capital investment:		
Mining	$1,200,000†-$1,300,000	$1,900,000†-$2,100,000
Retorts	3,500,000	5,500,000
Others	1,000,000	1,400,000
Total	$5,700,000-$5,800,000	$8,800,000-$9,000,000
Per ton of shale a day	912-925	880-900
Per barrel of shale oil a day	1,140-1,160	1,640-1,670

* Data presented by A. J. Kramer, senior refinery engineer, Bureau of Mines, Department of the Interior (7, p. 316).

† Based on recent mining developments at Rifle, Colo. (13, p. 12).

Assuming an investment of $1,200 to $1,300 per barrel of gasoline daily for a modern petroleum refinery; assuming, as a guess, that the investment for refining facilities for gasoline from shale oil would be about the same; and again assuming a 60 per cent yield of gasoline from shale oil (only the case for maximum gasoline production along with coke), these figures yield an estimate of 310 million to 463 million dollars for the investment required to produce 100,000 bbl of gasoline daily.

According to an estimate made recently by the Bureau of Mines, a plant to produce 21,480 bbl of gasoline daily from 20,000 bbl of shale oil by hydrogenation would require an estimated capital investment of $55,670,000, or about $2,590 per daily barrel of gasoline (13, p. 44). On the basis of this figure and an assumed yield of 82 per cent, the total investment for production (including mining, crushing, and retorting) of 100,000 bbl of gasoline daily would be 398 million to 503 million dollars. Somewhat higher figures were recently given by E. V. Murphree (39). According to Murphree, an investment of $8,400 per daily barrel is required for maximum gasoline production ($6,100 per daily barrel for maximum middle-distillate yield). These figures are based on shale assaying 30 gal per ton and include investment required for retorting the shale in Colorado and transporting the shale oil by pipe line to California, where it is hydrogenated and then processed into gasoline by conventional refining techniques. In any case, it appears that capital investment for producing gasoline from oil shale is somewhat larger than that for producing a corresponding quantity from petroleum.

TAR SANDS

The terms "tar sand," "oil sand," "bituminous sand," and "asphalt rock" have been used interchangeably. No one of them accurately describes the entire range of occurrences to which they have been applied. Rocks other than sands carry tar, or bitumen, and the term asphalt does not in all instances describe the impregnating substance. In this report tar sand has been used because of its general acceptance, even though in some instances it is a misnomer.

Geographic Distribution. The geographic distribution of the most extensive deposits of tar sand in the United States and Canada is shown on the map of Fig. 56. There are a multitude of minor occurrences, beleived in each instance to amount to no more than a few thousand tons, and the locations of these relatively unimportant occurrences have not been indicated.

Except for the tar sands of the province of Alberta in Canada, the map does not indicate the location of occurrences that are not revealed by surface exposures, although such occurrences may comprise some of the most important potential reserves. In the oil-yielding areas of the United States there are many sands heavily impregnated with asphalt or bitumen at depths ranging from a few feet to more than 100 or 200 ft. These concealed tar sands have not been included in any of the published estimates of the potential reserves represented by tar sands, and no further reference to them will appear in the present discussion.

Geologic Distribution. Tar sands are found in either the United States or Canada in rocks belonging to all geologic periods. With a few outstanding exceptions, they occur in regions in which some oil fields have been found. In such areas the tar impregnations are found either in rocks which yield true petroleum in nearby fields or in beds above or immediately below those which contain true petroleum in the oil fields of the area.

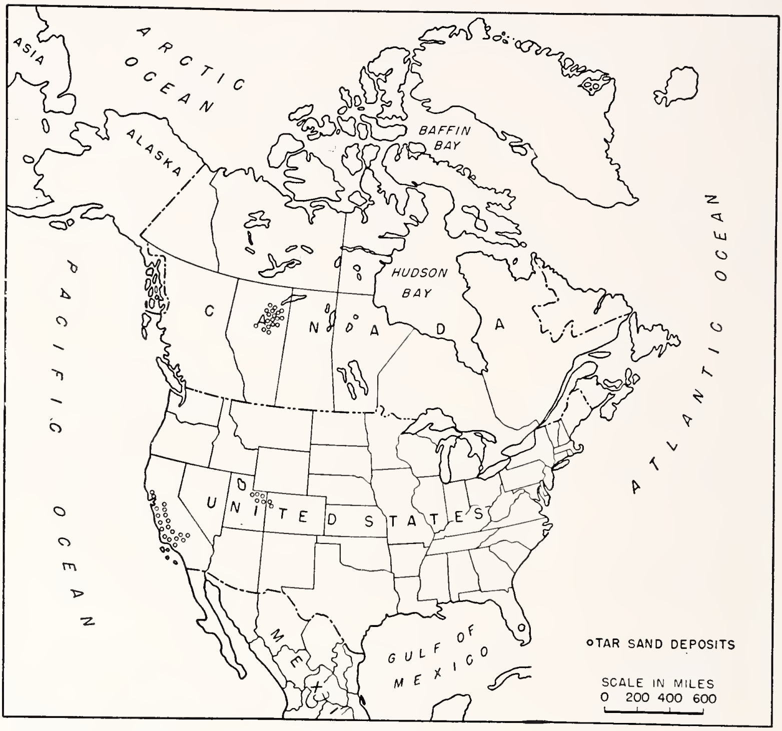

Fig. 56. Location of North American tar-sand deposits.

Most of the oil fields of the United States and Canada are found in rocks of Ordovician, Devonian, Mississippian, Permian, Cretaceous, and Tertiary ages. The same is true of the bituminous rocks.

Rocks of Cretaceous and Tertiary ages have yielded more great fields in the United States and in Canada than have the rocks of other ages. The greatest known accumulations of tar sands are also in rocks of Cretaceous and Tertiary ages.

Origin and Nature. With the exception of the very extensive tar sands of Alberta, Canada, and of the tar sands in northeastern Utah and adjacent Colorado, these deposits appear to be residues of petroleum that once was liquid and reached its present position when it was fluid and capable of moving appreciable distances through porous rocks. Many of the occurrences can appropriately be called "fossil oil fields." In these fossil oil fields it is apparent that oil once filled a porous rock stratum on top of an anticline or other structural trap. Erosion of the overlying formations exposed the oil-bearing stratum, and all that now remains is a porous rock impregnated with heavy bitumen. It has been assumed that the light constituents of the original petroleum escaped by evaporation, but this has not been proved. Oxidation and other chemical action may have played an important part.

Other occurrences of bituminous rock are in beds now inclined or tilted, but where there is no obvious anticline or trap. Liquid petroleum apparently migrated up the slope of a porous bed, and when the outcrop was reached, the light components were lost by evaporation, perhaps aided by chemical action. The remaining tar, or asphalt, plugged the pores of the rock so that later increments of migrating oil could not escape. In some instances true petroleum occurs against this dam of bitumen, but in others all that now remains is an estensive volume of bituminous rock.

Some deposits of tar sands are in rock that is not so permeable or open-textured as either sandstone or porous limestone. In such occurrences the rock apparently was rather extensively shattered so that petroleum could reach and impregnate large volumes. As in the other instances mentioned, this original petroleum later was modified to tar or asphalt.

The tar sands of an area in northeastern Utah and adjacent Colorado, centering near the town of Vernal, originated in a different manner, and the bitumen in the sands may be quite different in nature from that in deposits which had a different origin. These tar sands were not impregnated orignally with liquid petroleum. The bitumen was hard or plastic asphaltic material before it was incorporated in the sands. The geologic evidence suggests that, adjacent to the area in which the tar sands occur, great oil fields in anticlines or other oil traps were exposed by erosion. The oil escaped from these fields into streams that drained the area, and that which did not evaporate settled to the bottom of the water and was transported in the form of little cylinders, balls, or pellets of soft asphalt mixed with sand, rolling or tumbling along with other debris carried by the streams. These streams discharged into a wide, flat area where the material—sand, mud, and asphalt—that had been carried mechanically by the water settled and formed beds of sand and conglomerate, with pellets of asphalt and grains and pebbles of sand indiscriminately mixed.

The Athabaska tar sands of the province of Alberta, Canada, comprise the most extensive known deposit of bituminous rock. No theory which has been proposed for the origin of this deposit seems to fit adequately all the observed conditions. On the basis of the geologic relations it is difficult to assume that the bitumen in this rock was ever a true petroleum. This tentative conclusion is supported by the present chemical nature of the bitumen, or tar. It has been suggested that the tar content of these sands is a product intermediate between the original vegetable debris and true petroleum.

Availability of the Supplementary Reserve of Bituminous Rock. No significant part of this supplementary reserve can be considered immediately available, since the cost of quarrying, or mining, crushing, and recovering the bitumen is substantially greater than the current cost of petroleum in most of the areas where these rocks are found. Also, it appears unlikely that the heavy bitumen can be converted into some of the important refined products obtainable from petroleum at a cost that will compare favorably with that of securing these same products from crude petroleum at the present time or until the cost of crude petroleum is substantially increased.

Discussion of Data. While the known deposits of tar sands are enormous in extent, it is fallacious to consider the bulk of such material as a potential reserve unless some new methods of recovery, *in situ*, can be developed. The proportion of the tar-sand reserves which can be used by conventional methods represents perhaps only 1 per cent of the total, or 1 to 2 billion barrels of oil—an almost negligible potential reserve.

The average tar sands yield about ½ bbl of oil per ton. The cost of mining and recovering oil from the easily accessible rich sands (those yielding as high as 1 bbl per ton) is said to be around $1 per barrel, and some estimates are lower than this.

The investment said to be required per barrel of gasoline per day ranges from $1,335 to $3,300; the latter figure seems more credible. Little has been published on the conversion of crude to gasoline and other petroleum products, but modern refining methods are being studied by several petroleum companies.

Man-power requirements should not be out of line with other substitute sources. No estimates have been made of steel requirements, but these should not exceed the working of oil shale.

Reserves. The total oil reserves contained in known Western Hemisphere tar and oil sands have been estimated by Robert P. Russell as 38.5 billion tons of oil, or about 275 billion barrels (7, p. 44). The largest single deposit of tar-saturated sands in this hemisphere is found in the northern part of Alberta Province, Canada, extending along and back from the Athabaska River and its tributaries. Estimates of the oil content of these deposits made by a number of United States and Canadian geologists range from a minimum of 100 billion to 250 billion barrels, with some estimates running as high as 500 billion barrels (1). By far the greater part of these beds is buried beneath 500 to 1,800 ft of shale, sandstone, and glacial drift, and their mining would entail not only the cost of shafting and expense of hoisting but also expensive timbering costs, making the cost of underground mining prohibitive. Even along streams where the tar sands lie almost completely exposed, some sections are covered with too thick an overburden for mining under present economic conditions, the top economic limit for removal of overburden being about 1 cu yd for each ton of sand mined. About 10 to 20 sq miles of the deposits, containing between 500 million and 1 billion barrels of oil, are said to be workable by open-pit mining, and it is these which are considered possible sources of additional petroleum. While the presently recoverable oil in the Athabaska field amounts to only ½ to 1 per cent of the total oil estimated in the field, it still represents a sizable figure (5).

Tar-sand deposits are found extensively in California. According to W. E. Wrather, Director, Geological Survey, Department of the Interior, the San Luis Obispo region contains accessible bituminous material amounting to 282,880,000 short tons, much of which has a bitumen content of 11 per cent by weight (8). Massive formations of oil-impregnated shales and silts of varying thicknesses occur in the Casmalia area. Bituminous sandstone, containing about 10 per cent of asphaltic material, or about 10 million barrels (9), is found in the Santa Cruz Mountains area about 5 miles northwest of Santa Cruz. Along the southern base of San Rafael Range in Santa Margarita formation of the San Luis Obispo region is a highly enriched sandstone covering an area of approximately 6 sq miles and averaging 200 ft in thickness. The deposit has been estimated to comprise over 50 million cubic yards of bituminous sands. In general, it may be said that the principal tar-sand deposits in California occur in the immediate region of the Coast Range on both the east and west slopes and at several points within the range. In addition, the oil-bearing sand outcrops near McKittrick and Maricopa in western Kern County are promising sources of recoverable oil (48).

Utah possesses large deposits of tar sands, particularly in the Uintah Basin. In 1943, Herbert B. Maw, the governor of the state, stated that there are sands in this basin "one ridge of which has been studied, and it has been established in that one ridge that there are from 1.5 billion to 3 billion barrels of oil" (7, p. 277).

According to Bert Dyer of the Geological Survey, Department of the Interior, "the oil sands of Utah are found in the Uintah Basin and near the Colorado line south of the Uintah Basin, some on the San Rafael Swell, and at Sunnyside, Utah. In one strip in the Uintah Basin there is an outcrop of about 12 miles; one strip is about 2½ miles long and about 1½ miles from the outcrop, which would yield 600 million barrels" (7, p. 329). Desposits near Sunnyside have recently been estimated to contain 1,600 million cubic yards of bituminous sandstone, which could yield 728 million barrels of bitumen. Thicknesses of beds in this region range locally as high as 350 ft (15). Another source places total United States reserves as equivalent to 3 billion barrels of potential gasoline, the bulk of the reserves being in Utah and California (16).

Oil Yields. Tar sands vary in oil content up to about 25 per cent by weight. In addition, the size of the sand grain and other factors determine the susceptibility of the sand to separation by the action of hot water. The addition of sodium silicate or other alkaline reagent is often made to the water to facilitate the extraction. Bearing in mind that tar-sand deposits vary in oil content from each other and even within each deposit from spot to spot, some figures may be given on the amount of oil recoverable from these sands.

In the Athabaska field, a plant which processed 600 tons of tar sand per day recovered about 550 bbl of oil therefrom, or about 0.92 bbl per ton of sand processed (31). Because of the sensitivity of this oil to heat, yields of 25 to 35 per cent gasoline can be obtained without pressure cracking. So far as is known, no actual pressure-cracking tests have been made, but other small-scale experiments lead to the belief that high yields of 80-octane gasoline may be produced (5). The sands treated were high grade, containing about 16 per cent bitumen and 5 per cent sand of less than 200 mesh. The average sand would be more likely to contain about 12 per cent bitumen and a higher percentage of sand below 200 mesh, probably about 25 per cent. The significance of the fine-sand content is, of course, that it complicates the separation process (6).

A recent survey in the San Luis Obispo region indicates that deposits there contain about 11 per cent by weight of bitumen, or 26 gal per ton (8). The shales and silts of the Casmalia area contain up to 20 gal of oil to the ton (0.475 bbl per ton). Surface samples taken at random from the impregnated sandstone at the base of the San Rafael range showed bitumen contents equivalent to 15 to 20 gal of oil per ton (0.36 to 0.48 bbl per ton). The bitumen content of the sandstones of the Santa Cruz district, as indicated by samples taken from several quarries, averages about 14 to 16 per cent by weight (48).

No figures were found for yields or estimated yields from the tar sands of Utah.

Costs of Production. Costs of operations for production of crude from tar sands have been based on operation of small-scale plants which attained only limited and often-interrupted production. Even the more recent estimates are based on a noncommercial-scale project undertaken jointly by the Alberta provincial government and Oil Sands, Ltd. According to W. E. Adkins, who represents the Alberta government, at the present stage of the project, the cost per barrel of crude is about 99 cents. Mining, separation, and supplying of power and steam requirements account for the bulk of this cost (about 25, 36, and 25 per cent, respectively). Stripping of 4 ft of overburden accounts for less than 1 per cent of the cost. It should be remembered, however, that in sites less favorable with respect to overburden this proportion would be increased. Adkins remarks further that, although economies possible in large-scale operation are still difficult to predict, crude production at 65 cents can be expected based on separation at 50 cents per barrel maximum and mining at 15 cents per cubic yard. The latter figure is believed by largest manufacturers of earth-moving equipment to represent the maximum mining cost (1). Based on experience gained in operating the previously mentioned 550 bbl daily plant, it has been proposed to build a plant in the Athabaska field which would be capable of producing 10,000 bbl daily of digested crude oil (bitumen from tar sand, the viscosity of which has been reduced by short treatment at moderate temperature). This oil would be hauled or piped to Edmonton and there refined. Although operating data for this plant are not at hand, the statement was made in 1943 that the cost per gallon of 76- to 78-octane gasoline from this operation would be competitive with the cost at Calgary of gasoline made from crude from the Turner Valley fields (5). The field price of 44°API Turner Valley crude at that time was about $1.55 per barrel (32). It would appear, then, that the cost of gasoline from the economically obtainable portion of the Athabaska sands would not differ greatly from that refined from United States crude oils. Evaluating these same sands, another source stated that, assuming oil from the sand deposits remains steady, operations on a scale of 10,000 bbl daily could lay crude down at the refinery for about 75 cents per barrel (5).

In 1936 it was proposed to build a plant to separate oil from the sands in a chamber dug underground in the sand area near McMurray, Alberta, to facilitate handling some of the sands covered by thick overburden. If this is ever done, it may point the way to the placing of machinery for treating the tar sands underground in oil fields. The cleaned sand and other waste material would probably be used as backfill. Costs, it was estimated, would not be excessive; and when the industry actually needs all the oil in the oil fields, it was thought that serious consideration might well be given to underground mining and treating of tar sands (20).

The tars sands of California in a number of regions average as high in oil content as Athabaska sands, but an important factor in the cost of production of oil from them is their susceptibility to the hot-water extraction process. Recent tests on samples of Kern

River sands have shown they are amenable to water separation. There are some indications that sands from regions which were formed by marine deposits may not be so readily susceptible to water treatment. No figures were found for the cost of production of oil or gasoline from California sands, but it would seem safe to say that the best regions could compete favorably with those of Athabaska.

The extent to which the crude from tar sands must be processed in order to obtain aviation gasoline, diesel oil, and fuel oil is not known. An answer to this question is necessary before much can be said about refinery costs. It is understood that tests are being made on hydrogenation, thermal cracking, and catalytic cracking of tar-sand crudes in the laboratories of at least two United States petroleum companies (6).

Man-power Requirements. The number of men required to mine and process enough tar sand to supply a refinery of specified size depends primarily on two factors, (*a*) the method of mining which may be employed and (*b*) the method of separation usable. The consolidation of the sands and the amount of overburden determine the former, and the size of the sand particles and character of the bitumen influence the latter. Based on the small plant operating in the Athabaska field, 600 tons of sand have to be mined and processed to obtain 550 bbl of crude. By straight extrapolation of this figure to a plant capable of putting out 100,000 bbl of crude a day, the amount of sand to be handled would amount to approximately 110,000 tons. The preferred method of mining the sand is by light blasting, loading with power shovels, and trucking to the separation plant. The presence of overburden or the necessity for mining sandstones, shales, or sands to which the above method is not applicable will naturally increase further the man-power requirement.

The man power necessary to operate an integrated extraction-refinery setup is difficult to estimate, for no figures are available for the man-power requirements of the mining and extraction operations. It would seem that the total man power to produce the crude would be made up in by far the greatest share by those engaged in mining and transporting the sand to the extraction plant, since the actual separation process would require only a few men to control the operation of the pulpers, quiet-zone settlers, diluent mixers, and oil settlers. Refinery man power probably could be expected to be about the same as that necessary to produce the same amount of equivalent products from ordinary crudes. Exceptions to this assumption must be made to the extent that special operations such as hydrogenation may be necessary to obtain the desired products.

Steel Requirements. Although no total steel requirements were given, the number and sizes of pieces of equipment necessary for a 550 bbl daily plant are available. This information is included in case one versed in process equipment may care to extrapolate the requirements of this plant to those of full-scale operation. As used in the small plant, the pulper consists of a rotating horizontal steel cylinder about 8 ft in diameter and 20 ft long, resting on trunions and rotated by a chain drive. It is in this that the hot water and sand are brought into contact and separation takes place. Two flotation cells are used, a diluent mixer and an oil settler. Much of this equipment is steam-jacketed. A boiler plant would of course be necessary, though no figures on the size needed are available.

Investment Required. Based on information and experience available in 1941, the Abasand Company estimated that a plant to produce 10,000 bbl of crude daily from Athabaska sands would necessitate a total investment of about $4,850,000 (including $350,000 for pipe lines) and that a refinery to process the crude would cost about $3,150,000, the total investment being about $8,000,000. It was estimated that the plant would give a steady supply of products from 10,000 bbl of 20 to 22°API crude per day for 20 years, with another 20 to 30 years of production for a comparatively small expenditure in moving the site of the extraction plant in order to get at new sands (18*a*). The investment required to produce 100,000 bbl of crude per day, on the basis of an assumed 10 plants of 10,000 bbl daily capacity each, would probably be in the neighborhood of 48.5 million dollars. The new Alberta government plant at Bitumount, Alberta, which was nearing completion in April, 1948, will be capable of producing approximately 2 million gallons of finished products annually (about 132 bbl daily). Operations of the plant reportedly will be aimed primarily at obtaining cost and operating data. The plant's separation unit will be capable of running 350 bbl per stream-day. A unit of this size was chosen since it was felt that if operations were conducted on a smaller scale it would be difficult to extrapolate operating data to large-scale proportions (2). In 1947, Adkins (1) said that the investment cost per daily barrel of production at this plant would would be approximately $1,010. This includes mining equipment, separation plant, and 60 per cent of the investment in the power house (portion allocatable to separation). Extrapolation of this estimate for the production of 100,000 bbl daily gives an investment requirement of about 101 million dollars, or over twice that given above. Even so, Adkins's estimate is considerably lower than a reported investment requirement of $3,460 per barrel of daily crude-oil production in Turner Valley.

Based on the previously mentioned refinery investment of $3,150,000 for a 10,000 bbl per day plant, the refinery investment to process 100,000 bbl daily of tar-sand crude would be about $31,500,000. Thus a total investment for obtaining and refining the crude of 80 to 132.5 million dollars would be required. Expected gasoline yields are a minimum of 35 per cent even before cracking; thus, taking 60 per cent as a rough guess, 52.5 million dollars would be required for refinery facilities to produce 100,000 bbl of gasoline per day; and the total investment for mining, extraction, and refining tar sands to yield this production would be 133.5 million to 221 million dollars. The smaller figure seems ridiculously low as compared with the comparable investment for petroleum production and refining facilities. It seems possible that the actual investment required might be twice this value; this would certainly be the case if hydrogenation were to be used instead of the thermal process. A 1944 investment estimate of $3,300 per barrel of gasoline seems more credible; for 100,000 bbl of gasoline per day, by this estimate, 330 million dollars would be required.

NATURAL GAS

Discussion of Data. If all of the known and estimated natural-gas reserves of the United States were used for the Fischer-Tropsch synthesis of petroleum products, some 15 billion barrels of oil might be obtained. It is believed, however, that natural gas is not likely to be diverted from its present valuable uses and that only a small proportion will be available as a substitute source. On the other hand, natural gas in moderate supply appears to offer the cheapest starting point for synthetic petroleum. One commercial plant is now under construction, and it is believed that several oil companies may build and operate plants to secure specialized petroleum products and at the same time to obtain commercial experience in the second phase of the Fischer-Tropsch process—a phase which is common to the process as applied to coal.

From 10,000 to 12,000 cu ft of gas is required for 1 bbl of gasoline. However, future developments may reduce the gas required to as low as 8,400 cu ft per barrel. Cost estimates as low as 5 cents per gallon of gasoline have appeared in the literature. Recent estimates range from 9 to 13 cents per gallon, but there is reason to believe that under 1948 economic conditions the cost may run somewhat higher.

Man-power requirements should compare favorably with normal petroleum refining, and steel requirements have been estimated as low as 2.8 tons per barrel of gasoline per day. The investment required has been estimated as low as $2,200 per barrel per day, but under present-day economic conditions the investment might run somewhat higher.

Reserves. "The present proved reserve of natural gas is about 174 trillion cubic feet. . . . We have no way of guessing the ultimate reserve of natural gas except that we can be sure it is larger than the proved reserve. Dr. E. De Golyer has made a conservative estimate of 200 trillion and has pointed out the interesting fact that 80 per cent of the gas reserves are located in about 2 per cent of the producing fields. He expects the ratio of gas to oil to increase in the future. If he is correct in this expectation, an estimate of 400 trillion would have at least the same validity as the minimum estimate for ultimate petroleum production. Additions to natural-gas reserves have been found at a greater rate than the gas has been produced. This is partly because of lack of pipe-line facilities to gather and to transport the gas to markets. It is probable that the rate of useful consumption of gas could be greatly increased" (18).

R. C. Alden and A. Clark recently presented the data given in Table 6 (3). It may be seen that 10 states contain 98 per cent of the reserves. On the basis of limited data, Canadian reserves appear to approximate 5 trillion to 10 trillion cubic feet, roughly comparable with those of California.

It is felt by many that natural gas is too valuable a substance in its own form to be considered as a supplemental reserve for the production of a synthetic petroleum, and it is obvious that, even were it commercially feasible, the total national reserves, approximated at 170 trillion cubic feet, could serve to provide (if used as Fischer-Tropsch raw material) no more than about 15 billion barrels of a synthetic petroleum if all other uses were disregarded. Those who have studied natural-gas conversion from the standpoint of possible plant sites have estimated that as much as about 22 per cent and as little as about 2 per cent of natural-gas production might eventually be used for liquid-fuels production. A guess of about 5 per cent seems credible. If this is correct, the total production of synthetic gasoline from natural gas would amount to only a little more than 2 per cent of total gasoline demand in this country. In order to pay out an investment in a synthesis plant, there should be available about 1 trillion cubic feet of gas—enough to supply 100 to 120 million cubic feet a day for 20 years. It is not enough to have a proven reserve of this magnitude; the reserve must be great enough to permit withdrawal of gas at an undiminishing rate for the entire period. It is true that many of the largest gas fields are far removed from consuming centers and at present are not even accessible to pipe lines, but many feel that the economic value of such gaseous fuels is so high that they should be reserved for use in their present physical form. Nevertheless, a vast amount of attention has been paid to natural gas by petroleum companies in this country, for it is now generally accepted that it constitutes the cheapest raw material for the synthesis of a synthetic petroleum—potentially competitive with natural petroleum, perhaps. There is a definite feeling that no government research should be devoted to such developments, although the

TABLE 6. ESTIMATED PROVED RECOVERABLE RESERVES OF NATURAL GAS IN THE UNITED STATES (3)

State	Trillions of cubic feet	State	Trillions of cubic feet
Texas	90.0	Mississippi	2.5
Louisiana	23.5	West Virginia	1.8
Kansas	14.6	Kentucky	1.4
Oklahoma	11.4	Wyoming	1.2
California	10.2	Others	3.3
New Mexico	6.0		
		Total	165.9

synthesis step in the Fischer-Tropsch process is the same for any raw material which yields the desired water gas in the first step.

Oil Yields. G. G. Oberfell (42) has stated that improved reaction efficiencies and, particularly, improved techniques of synthesis gas production will no doubt reduce the amount of gas required so that net yields in large-scale operations may be as high as 4.5 to 5.0 gal of motor fuel per 1,000 cu ft (8,400 to 9,330 cu ft of the latter per barrel of motor fuel).

Representative of modern processes are the Hydrocol and Synthol variants of the Fischer-Tropsch process. P. C. Keith has reported that Carthage Hydrocol's Brownsville, Tex., plant "has been designed to process approximately 64 million cubic feet of natural gas per operating day and to produce 5,800 bbl per day of motor fuel, 1,200 bbl per day of synthetic diesel oil, and 150,000 lb per day of crude alcohols (in water solution)" (33). "It may be noted that the proposed operation calls for the recovery of approximately 0.25 gal of natural gasoline and butane per 1,000 cu ft of feed gas, so that this 381 bbl per day of motor-fuel blending agents is presumably part of the plant's gasoline output. Including this, the Brownsville plant will have a gasoline yield of 1 bbl per 11,000 cu ft of natural gas and a total hydrocarbon product yield of at least 1 bbl per 9,150 cu ft" (50). Keith stated that "in the next several years, improvements in the Hydrocol process will make possible the production of 1 bbl of oil from 8,000 cu ft of gas, including all gas used for fuel" (33). According to Paul Ryan, the Synthol process will require approximately 11,000 cu ft of natural gas to produce 1 bbl of "liquid-hydrocarbon products" (45).

Data recently reported by R. C. Alden and A. Clark (3) indicate a yield of 1 bbl of "motor fuel" per 10,000 cu ft of natural gas, while data released by E. V. Murphree *et al.* (40) give a yield of 1 bbl barrel of "oil" per 12,000 cu ft of gas. It may be seen, therefore, that natural-gas requirements range from about 10,000 to 12,000 cu ft per barrel of gasoline and that future developments may reduce gas requirements to as low as 8,400 cu ft per barrel.

Cost of Production. Based on natural gas at 5 cents per 1,000 cu ft and allowing credits of 3.5 cents per gallon for diesel oil and 0.5 cent per pound for crude alcohols, it was predicted in 1946 that the "out-of-pocket" cost of the gasoline at Carthage Hydrocol's Brownsville, Tex., plant would run about 2.5 cents per gallon.

This cost includes all expenses and charges exclusive of capital costs. When capital costs, including interest, depreciation, and amortization, are added, the cost of the gasoline would be 5.25 cents per gallon (33).

Cost estimates appearing in the recent literature are considerably higher than those given above. This undoubtedly is a reflection of constantly changing price levels which have prevailed in the last few years. Early in 1948, R. C. Alden and A. Clark (3) reported a cost of 9.14 cents per gallon of motor fuel, based on natural gas at 10 cents per 1,000 cu ft and including amortization and interest but without credit for by-products. E. V. Murphree's (39) recent estimate of 12.8 cents per gallon is based on natural gas at 10 cents per 1,000 cu ft and includes amortization and return on the investment for manufacturing and on that part of the transportation investment peculiar to the plant. In addition, Murphree's cost includes credits for by-products and charges for product transportation from the Gulf coast to the eastern seaboard marketing area.

It was reported (17) in February, 1948, that gasoline made from natural gas was competitive in cost with gasoline from $2.50 per barrel crude. At about the same time, P. C. Keith was quoted as saying, " 'Refining' costs with natural gas are slightly higher than with petroleum, but production costs are less, and the two factors balance out" (25). According to Keith, "the cost of gasoline made from 10 cents a thousand gas, even ignoring chemical credits, will be less than gasoline made from $2.75 crude" (34).

Man-power Requirements. No data are immediately at hand. Man-power requirements for natural-gas production would be low. For the crude-oil- and gasoline-production steps, such requirements should be somewhat lower than for Fischer-Tropsch synthesis from coal.

Steel Requirements. According to a recent statement by P. C. Keith (34), the steel requirements for a 10,000 bbl per day Hydrocol plant are about 2.1 tons per barrel a day. Somewhat higher figures have also appeared in the recent literature. R. C. Alden and A. Clark (3) have reported a figure of 6.1 tons per daily barrel of "oil," while Bruce K. Brown (37) has estimated 7.0 tons. E. V. Murphree (39) estimates a steel requirement of 7.1 tons per daily barrel for maximum middle-distillate yield and 7.9 tons per daily barrel for maximum gasoline yield. Mr. Murphree's figures, however, include the steel needed for production, transportation, refining, and delivery of Gulf coast oil to the consuming market on the eastern seaboard. For the production of 100,000 bbl of gasoline per day, therefore, some 280,000 to 790,000 tons of steel would be required, whereas 210,000 to 710,000 tons would be required for the production of a similar amount of oil. These figures would indicate steel requirements comparable with, or somewhat less than, those for natural petroleum since Murphree stated that his estimate of 7.9 tons per daily barrel of gasoline is essentially equal to that for petroleum.

Investment Required. Estimates appearing in the recent literature range from $2,500 to $4,500 per daily barrel of oil. These estimates are as follows: Bruce K. Brown and R. C. Gunness (21), $2,500 to $4,000; P. C. Keith (34), $3,000 to $3,500; R. C. Alden and A. Clark (3), $3,000 to $4,000; and E. V. Murphree (24), $4,000 to $4,500. E. V. Murphree (39) has also given investment costs which include not only manufacturing but also facilities for the production and transportation of the raw materials and, in addition, the transportation of products to stated marketing areas. Murphree said that a plant located in the Gulf coast area, the products of which would be marketed on the eastern seaboard, would cost $7,400 per daily barrel for maximum middle-distillate yield and $8,200 per daily barrel for maximum gasoline yield. Corresponding figures for production from petroleum, according to Murphree, are $4,300 and $6,500 per daily barrel, respectively.

In 1947, P. C. Keith (11) stated that an investor could afford to spend $4,250 per daily barrel and pay off the plant in 5 years. He said investment costs of a present-day 10,000-bbl refinery amounted to $4,200 per daily barrel. It was estimated in 1945 that "a complete Synthol plant to produce a large volume of liquid hydrocarbons would have a pay-out time of approximately 8 years. A combined Synthol and chemical plant would have a pay-out time of approximately 3 years. This acceleration in financial return is due to increased values of the chemical compounds over the values of the hydrocarbons" (45). Early in 1948, the M. W. Kellogg Co. (14) estimated the capital investment cost for a Synthol plant at $4,000 per daily barrel of synthetic crude oil. These figures are not very much higher than corresponding investment figures for petroleum production and refining. It is believed by some that gasoline production by the two routes is approaching economic competition.

Agricultural Materials

Agricultural materials offer small reason for detailed attention at present, since the recent war has conclusively shown that the ethyl alcohol industry (including beverage distillers) has had trouble finding agricultural raw materials to permit an output of about 600 million gallons of ethyl alcohol per year (approximate annual wartime output); this amount, even if available for fuel purposes, would only fractionally supplement the 780 million barrels of gasoline consumed in 1947, and alcohol could not be used as a source of fuel oils and lubricants. Experimentation is under way on processes to produce ethyl alcohol (*a*) from the waste sulfite liquors of paper mills (which could add a theoretical maximum of 100 million gallons of ethyl alcohol per year) and (*b*) from sawdust or wood chips. The chief appeal of these processes seems to be the aid they may lend in time of war (for synthetic rubber and munitions) if plants using them can be placed in operation in time; potential ethyl alcohol costs of 20 cents or less per gallon are often mentioned, but so are estimates of 50 cents per gallon, at least at first.

Ethyl alcohol from grain, incidentally, during the recent war cost well over 50 cents per gallon, a prohibitive price were it to be considered as a gasoline substitute. The supply of blackstrap molasses, long the cheapest agricultural raw material, is strictly limited even in times of peace, since it is a waste product in sugar manufacture; the use of invert molasses (molasses containing extractable sugar) increases costs considerably.

Fuels other than ethyl alcohol, of course, may be synthesized from agricultural materials. Abroad, ketone-alcohol mixtures are being so prepared and used. Such fuels appear no more economic than alcohol, however, and again no fuel oils or lubricants are formed.

It has been estimated that gasoline can be made from vegetation by the Fischer-Tropsch process at lower cost than alcohol by fermentation.

Agricultural raw materials, except possible waste products, are notoriously undependable substances for chemical synthesis, since bad growing seasons can decimate crops. Whatever consideration they warrant should be directed toward research on the use of waste cellulosic materials, although even here economic potentialities seem far poorer than for any other liquid-fuel substitute.

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Chapter VIII

THE BUREAU OF MINES DEMONSTRATION PLANTS IN THE SYNTHETIC-FUELS PICTURE

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The production of synthetic liquid fuels in the United States is of vital importance to both its peacetime economy and its wartime security. This fact is recognized by industry and our government. Research and development work by industry in this field was in progress before the Second World War and has been intensified after it.

The Seventy-eighth Congress, seeing the need of government participation in the work, created Public Law 290 in April, 1944. The bill was introduced and vigorously prosecuted by Senator Joseph C. O'Mahoney.

Public Law 290 authorized appropriation of 30 million dollars and a five-year study of the production of synthetic liquid fuels from coal, oil shales, agricultural and forestry products, and other substances. This work, to be performed under the Bureau of Mines, was intended to develop in laboratory and in pilot- and demonstration-plant units means and methods for deriving liquid fuels from materials other than petroleum. After the law became effective, the Bureau of Mines intensified its scientific work in synthetic fuels at existing stations and initiated new research at several new installations especially designed for the purpose. The Office of Synthetic Liquid Fuels, Bureau of Mines, was set up to direct the program.

The work at the Pittsburgh central research laboratories on the hydrogenation of coal and the Fischer-Tropsch synthesis of hydrocarbons from water gas was intensified and has been extended to include research and development on means of gasifying coal. A laboratory was built at Bruceton, Pa., and dedicated on May 21,

1948. This laboratory's prime function is concerned with the development of synthetic liquid fuels from coal.

A laboratory was built at Laramie, Wyo., for research on oil shale and recovery and refining of oil from oil shale. A station was also set up at Morgantown, W. Va., for research and development work on gasification of coal and purification of the gases as required for hydrogenation of coal or the Fischer-Tropsch synthesis.

At present, three demonstration plants are involved in the Bureau of Mines synthetic-liquid-fuels program. The first demonstration plant to be completed, at Rifle, Colo., is for the mining, recovery, and refining of oil from shale. At Louisiana, Mo., the hydrogenation demonstration plant for conversion of coal to liquid fuels by the Bergius process is nearly completed. Recently a contract was let for the design and construction of a second plant at this site, namely, the gas-synthesis demonstration plant, which will operate on the oxygen gasification of coal and Fischer-Tropsch synthesis.

A second act, known as the O'Mahoney-Case Act, passed by Congress on Mar. 15, 1948, authorized appropriation of an additional 30 million dollars to support the program and extended the work for an additional three years.

A bill introduced in February, 1948 by Representative Wolverton would make public funds available through the Reconstruction Finance Corporation (RFC) for the construction of commercial-size synthetic-fuel plants by private industry. In the hearings held, most witnesses favored the principles of the bill but objected to the details of enactment. The bill was revised by the House Commerce Committee with a unanimous recommendation that the revised bill be adopted.

According to various estimators, we have in the United States proved reserves of petroleum equal to twelve times our present annual consumption. Quoting Secretary Forrestal, we are short some 2 million barrels per day of domestic oil to meet immediate immediate military requirements in case of emergency, and, in 1948, for the first time in many years our consumption will exceed our domestic production. This is the stimulus for synthetic-liquid-fuels research, development, and production.

The magnitude of this problem is indicated by the fact that production of 500,000 bbl per day by the Fischer-Tropsch process would require 14 billion cubic feet of synthesis gas per day. Production of a similar amount by coal hydrogenation would require over 4 billion cubic feet of hydrogen per day. The solution of such problems must be a matter of long-term development.

The Bureau of Mines synthetic-fuels work is directed toward oil shale and coal as sources. Much of the country's present industrial research is based on the use of natural gas as a starting material. This latter work is predicated partly on the immediate availability of reserves of natural gas that are unsuitable and unavailable as premium fuel because of their high inert content or their remoteness and partly on the lower cost and simplicity of using gas. Many believe that the limited supply of natural gas should be conserved for its direct use in heating and that emphasis should be placed on converting coal to gasoline.

The Germans began their work in coal hydrogenation and Fischer-Tropsch synthesis on an industrial scale in 1926 and 1935, respectively. Some of their findings are incorporated, along with American innovations and improvements, into the hydrogenation demonstration plant at Louisiana, Mo.

In the Fischer-Tropsch field, the American industries have taken over the preliminary German work and introduced American streamlined chemical engineering and technique to improve the process thermally and economically. Virtually all of the major oil companies, some of them in conjunction with coal interests, are occupied in development work on the Fischer-Tropsch process. In general, the work has been confined to application of the fluidized technique for the synthesis step. Recognizing the magnitude of the problem, in many instances companies have teamed or pooled their efforts. One commercial plant to produce 7,000 bbl per day is in the initial stages of construction. It is to be pointed out that this process yields a variety of by-products, which have characteristics differing from and not competitive with those derived from coal hydrogenation or oil shale.

Question has been raised at times as to the utility of the demonstration-plant unit as a step in developing full-scale operation. It is felt that, in the processes under consideration here, the demonstration plant is necessary and valuable. Many of the laboratory- and pilot-plant data can be proved to advantage in an intermediate-size unit before a commercial size is constructed. In some instances, there are definite minimum operable sizes below which little useful information could be obtained. This is true, for example, in the coal hydro converters and in the coal gasifier.

Further, some problems involved are solvable only by actual operation and cannot be approached readily through analytical means. For example, until a coal gasifier is actually running under conditions comparable with those chosen for the final operation, little information can be obtained as to the constitution of this gas and the impurities present, especially those occurring in trace quantities. The final proof of the extent of purification needed must be the effect of the purified gas on the synthesis catalyst.

In addition to testing the laboratory and pilot-plant data and determining actual operating yields and compositions, it is necessary to procure information for the design of commercial-scale plants—rates of heat transfer and of reaction, service life on reaction materials and catalysts, and the like. Cost data must also be obtained for use in economic studies of the effect of locations, raw materials, and alternative processes.

A further function of demonstration-plant-scale operations is to develop and prove specialized commercial-process equipment. When work on the design of the plants was first started, it was found in some instances that no American manufacturer had the technique or equipment needed for manufacturing some items required in constructing these units. This applies particularly to coal hydro, with its attendant problems of high-pressure construction. Bureau engineers have worked in cooperation with the technical staffs of the manufacturers involved on developing the equipment and methods for its satisfactory and economical fabrication. Many manufacturers have expressed a strong desire to have their products a part of these plants in order that they may obtain sound information as to their performance under these new and specialized conditions.

Oil Shale—Rifle, Colo. The oil-shale demonstration plant at Rifle is in an area containing the largest portion of the total known reserves of oil shale in the United States. In the Rifle-DeBeque area of western Colorado, there are deposits of oil shale of relatively uniform thickness, the lower 90 ft of which will average more than 25 gal per ton, or about 125 million barrels per square mile. Above this is a bed 500 ft thick, which, together with the richer bed, will yield an average of 15 gal per ton, or 300 million barrels per square mile. The present information would indicate that there are about 1,000 sq miles of such deposits, which would give a total yield of 300 billion barrels, disregarding mining and retorting losses, equivalent to about 150 years' supply for the country at the 1948 estimated rate of use for petroleum.

The work at the demonstration plant is divided into two principal parts; one covers a study of mining and transportation methods, the other the retorting of shale and further processing of the crude shale oil to produce marketable products.

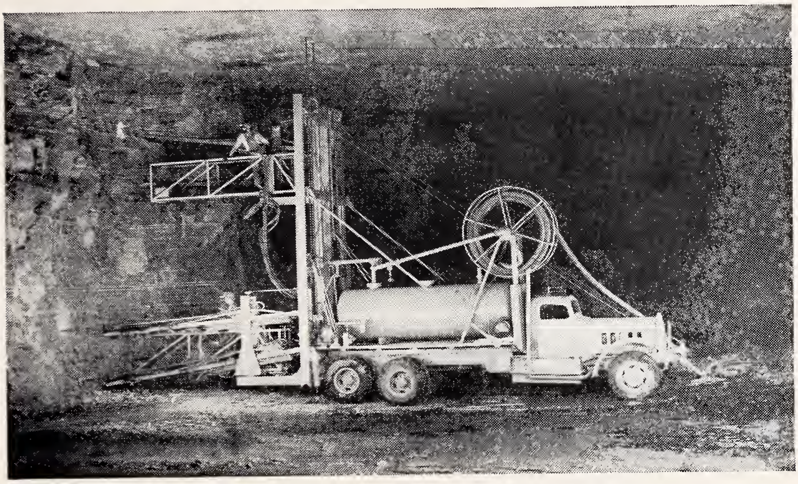

FIG. 57. Multiple carriage simultaneously drills four holes in shale, each 15 ft deep. (*U.S. Bureau of Mines.*)

The shale itself is a hard, unfaulted rock and makes a strong support for the overburden. Because of this, it has been found possible to mine from test rooms as large as 70 by 100 ft. Sag measurements and seismic records have indicated that there is no undue strain in the rock above such rooms. Adapting modern underground-quarry methods to such operations, it is possible to mine 50 tons of shale per man-shift, or almost ten times the average production in underground coal mines in the United States. If more highly mechanized equipment is installed, shale-mining rates should be further increased. The work done thus far has indicated that the cost of mining oil shale commercially with the most efficient practices might be as low as 60 cents per ton, equivalent to 84 cents per barrel of shale oil. Study of the mining and transportation of shale will continue, and these operations will supply the shale for the retorting studies at Rifle.

One advantage of shale in a synthetic-liquid-fuels program is the possibility of producing, in a short time, commercial quantities of heavy fuel oil that would be usable almost as recovered or that may be further processed to yield higher grade materials, such as distillate fuels, diesel oils, or motor fuel.

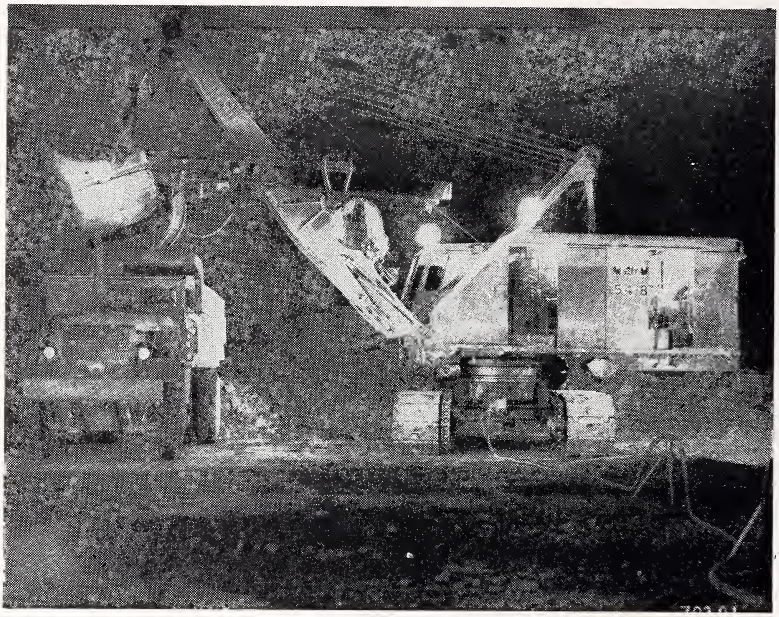

Fig. 58. In a single bite this electric shovel loads 3 cu yd of broken oil shale into a 15-ton diesel truck deep within the underground quarry at the Oil Shale Demonstration Plant of the Bureau of Mines near Rifle, Colo. (*U.S. Bureau of Mines.*)

The largest unit for shale retorting at Rifle is the N-T-U retort. It should be emphasized that the installation at Rifle was intended not as a forerunner of a commercial plant but as a means of studying basic reactions during retorting and of obtaining quickly supplies of shale oil large enough for a study of refining methods and quality of resulting products.

The shale as mined passes through two crushers in series to produce minus 3- to 4-in. material. The fines are removed, and the ½- to 3-in. material is charged, 40 tons to a batch, into the N-T-U retort. The top of the bed is ignited, and the hot products of the combustion are drawn down through the bed and sent to a vapor-condensation and recovery system and then to the waste-gas stack. This process uses the heat of combustion of the fixed carbon in the shale to distill oil from the shale in the lower portions of the bed. In addition to this operation, a number of pilot-plant studies of other retorting methods, potentially more efficient, are in progress.

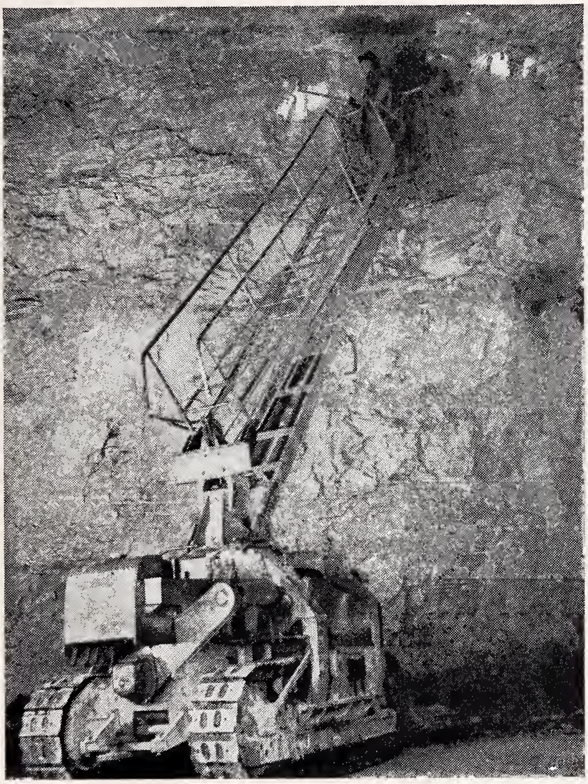

Fig. 59. Miners removing loose oil shale from the face and roof with the aid of a portable scaling rig in the underground quarry, Bureau of Mines Oil Shale Demonstration Plant. (*U.S. Bureau of Mines.*)

Retorting experiments have been made on the Hayes low-temperature coal carbonizer and on a flash-carbonization pilot plant operated by the Tennessee Valley Authority (TVA) at Wilson Dam, Ala. A similar plant, known as the Royster retort, is being studied, and a retort employing a transverse flow of hot gas through a narrow bed of crushed shale is being constructed at Rifle.

Negotiations for cooperative work on other retorts are pending. One project, in conjunction with the Union Oil Co., employs a continuous, internally fired, down-draft retort. A second pilot plant, utilizing the fluidized-bed technique, is to be operated on oil shale by the Standard Oil Development Co. at Baton Rouge, La.

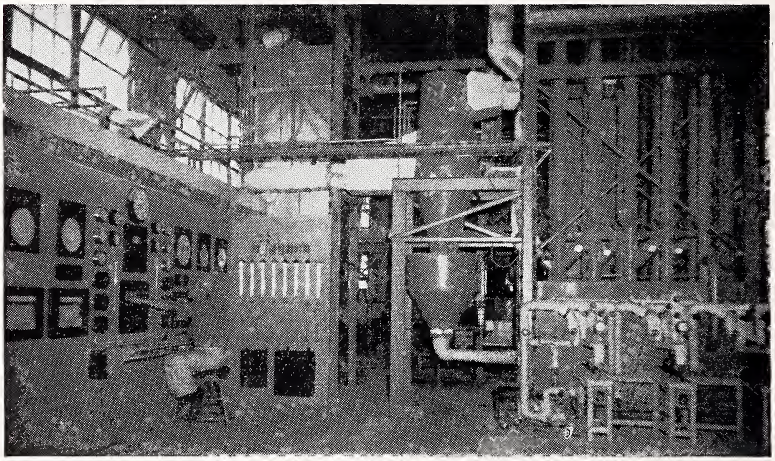

FIG. 60. Interior of pilot-plant building, Bureau of Mines Oil Shale Demonstration Plant. (*U.S. Bureau of Mines.*)

The oil recovered from normal retorting has the following characteristics:

Gravity, °API	20
Pour point, °F	90
Gasoline content, per cent	5
Furnace distillate, per cent	15
Gas-oil content, per cent	30
No. 6 fuel oil, per cent	50
Sulfur content, per cent	1.0

As has been stated, it is suitable for use as a high-viscosity fuel oil directly. The high pour point limits its use, but it has been found that, through a simple viscosity-breaking operation, the pour point can be reduced appreciably to about 20°F, with some increase in gasoline and furnace-distillate content.

In order to make higher grade materials, more extensive refining of the crude shale oil is necessary. Laboratory and pilot-plant studies are in progress on various possible methods, including thermal and catalytic cracking, mild hydrogenation, and others.

Demonstration-scale plants for viscosity breaking and for thermal cracking for gasoline production are being constructed at Rifle. Provisions for acid treating, rerunning, and doctor sweetening of the gasoline are included. It is to be anticipated that, as laboratory studies advance, more of the results will be embodied in larger equipment.

Coal Hydro—Louisiana, Mo. The coal-hydrogenation plant at Louisiana, Mo., was designed for operation at pressures up to 700 atm in two major steps: liquid-phase hydrogenation, which accomplishes liquefaction of coal, and vapor-phase hydrogenation, which converts the liquefied coal to gasoline and by-products (Fig. 61). The output of the plant will be 200 to 300 bbl of gasoline per day, depending on the coal and catalyst used. The primary chemical difference between coal and crude petroleum is that there is approximately twice as much hydrogen in the latter. Thus, for the hydrogenation of coal to finished gasoline, hydrogen amounting to approximately 9 per cent of the weight of the moisture- and ash-free coal has to be combined into the product.

The raw coal is crushed to minus 3- to 4-inch size, then pulverized to −60 mesh in a ball mill and dried to 1 or 2 per cent moisture content by a gas-fired recirculating drier. The pulverized coal is mixed with a small amount of catalyst and with heavy oil previously obtained from the liquid-phase process into a paste containing approximately 50 per cent solids. The catalyst will consist either of 1 to 2 per cent iron oxide or of 0.05 per cent tin oxalate as an alternate.

The viscous paste is injected into the paste preheater by a steam-driven plunger pump,working at 10,000 psi pressure. The preheater is of a modified radiant type, where the high-pressure tubing is protected by a superheated steam jacket. In Germany and England convection-type preheaters with finned hairpin tubes were used, and the temperature of the combustion gases was regulated by recirculation. Our calculations indicate that, regardless of which heating method is used, the criterion of the rate of heat transfer is always the past-film coefficient. In fact, leading American heating-element designers recommend direct radiant paste preheaters, as long as the over-all heat-transfer rate is kept in line with the design rate for steam-jacketed or convection-type heaters.

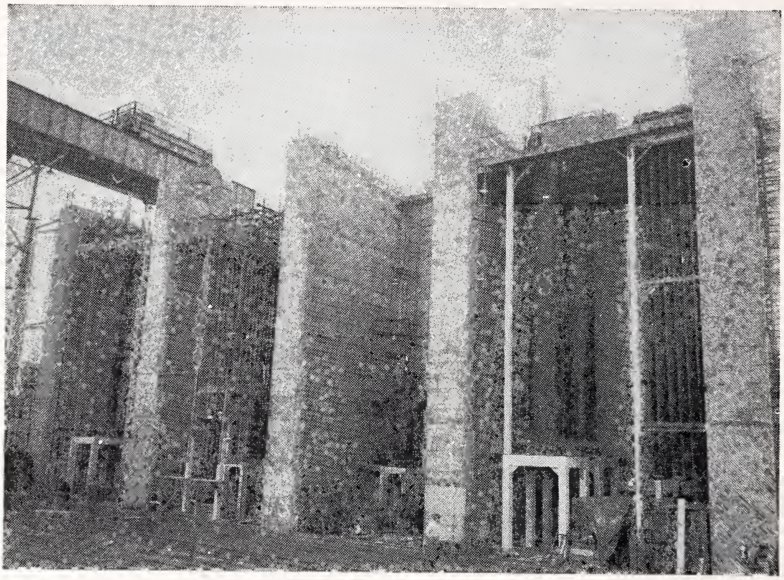

Fig. 61. Coal is converted to oil under high pressures in these massive forged-steel vessels at the Bureau of Mines Coal Hydrogenation Demonstration Plant, Louisiana, Mo. Nearly 43 ft high and 50 in. in diameter, the converters weigh approximately 100 tons each when fully assembled. (*U.S. Bureau of Mines.*)

Ahead of the preheater, a small amount of hydrogen is injected into the paste to reduce the viscosity, and the paste is heated in the preheater first section to about 550°F. At this stage, additional hot hydrogen and recycle heavy oil are added to jump the temperature to the 650°F level, circumventing the swelling-range difficulties that would occur around 600°F. At this temperature the coal would start to swell, and the paste would become dry and extremely viscous, with a resultant danger of coking and tube failure. After passing through the remainder of the preheater the mixture leaves at 815°F and passes into the first of two converters, which are 3 per cent chrome-steel forgings 32 in. in inside diameter and 35 ft high. The reaction "basket" is 24 in. in diameter, and the space between shell and basket is filled with a monolithic asbestos-cement insulation to keep the shell temperature below 500°F. This permits the full tensile strength of the metal to be utilized and eliminates danger of the high-temperature hydrogen attack. For 95 per cent conversion of the coal to liquid and gaseous products, the residence time is approximately one hour. The reaction is highly exothermic, and to maintain the reaction temperature at 935°F cooling hydrogen is added in controlled amounts to the converters at different points.

After the second converter, the reacted products enter the "hot catch pot," where the hydrogen and light products separate from the solid-containing heavy-oil fraction. "Letting down" the heavy oil to near atmospheric pressure is a difficult service because the hot liquid contains large quantities of absorbed gases and up to 30 per cent of abrasive solids. The heavy oil is freed from ash, catalyst, and unreacted coal by centrifuging or by flash distillation with 1100°F superheated steam. The oil fraction constitutes the bulk of the pasting oil used in the process. The solids removed continuously in the demonstration plant will have a heating value of approximately 9000 Btu per pound. For future commercial-size operation serious thought is being given to delayed coking of this residue.

The gases and vapors leaving the top of the hot catch pot are cooled in an exchanger system, and the condensed liquid and vapor are separated in the "cold catch pot." The gas from the cold catch pot, containing about 70 per cent hydrogen, is washed at full operating pressure with water for removal of NH_3, H_2S, and water-soluble salts and with oil for removal of light hydrocarbons. After this purification the hydrogen stream is recycled through the system with fresh make-up hydrogen. The liquid products from the cold catch pot go through the letdown system (where the pressure is reduced in two steps, first to 25 and then to 7 atm) and are charged to the liquid-phase distillation unit.

The bottoms from this distillation unit join the pasting-oil stream. Gasoline, naphtha, and middle-oil cuts are separated in the distillation unit to establish weight relations and to prepare, by blending, a feed stock of constant quality for the vapor-phase hydrogenation. This stock is combined with a nearly equal amount of vapor-phase recycle middle oil and saturated with H_2S or with sulfur for the vapor-phase hydrogenation step. The addition of some form of sulfur is necessary to preserve the activity of the vapor-phase catalyst.

The vapor-phase injection pumps, working at 10,000 psi pressure, push the charge and a small amount of hydrogen through a feed-product exchanger and a radiant-type vapor-phase preheater. The preheater outlet temperature is 920°F, and the charge is wholly in the vapor phase. This vapor enters a single converter having the same dimensions as the liquid-phase converters. There are six fixed catalyst beds in this vessel. The catalyst is fuller's earth, treated with 7.5 per cent hydrofluoric acid and impregnated with the compounds of zinc, molybdenum, chromium, and sulfur. This is a very rugged catalyst and at 700 atm performs the triple duty of the former German saturation, splitting, and dehydrogenation operations. The reaction is quite sensitive to temperature variations, and recirculated cooling hydrogen is added at every tray to keep the temperature between the 912 and 930°F operating limits. After the reaction is balanced, the feed-product exchanger provides most of the heat necessary for preheating, and the duty of the preheater becomes negligible.

The products then pass through a cooler and a cold catch pot, where the condensed oil and hydrogen are separated. The hydrogen is returned to the circulating compressor, and the liquid passes through a double let down to the vapor-phase distillation unit. The bottoms are recirculated to the vapor-phase hydrogenation system; the overhead is stabilized to a 10-lb radiant-type vapor-phase gasoline, caustic and water washed, and sent to final storage. All plant gases pass through an absorber before being used for fuel. Ammonia, CO_2, and H_2S liquors are treated with sulfuric acid before going to the sewer, and recovered H_2S is utilized to saturate the vapor-phase charge.

Make-up hydrogen of about 11 per cent by weight on the moisture- and ash-free coal is furnished from the former Missouri Ordnance Works natural-gas reformer, scrubber, and compressor system. Here natural gas is cracked with steam, and the resulting H_2 and CO are shifted with more steam to H_2 and CO_2. The mixture is compressed through three stages of a seven-stage compressor to 450 psi, and CO_2 is scrubbed out with water at this pressure. After the seventh stage, around 13,000 psi pressure, the remaining CO may be removed by catalytically reacting into methane and water. The result is a 98 per cent pure hydrogen for addition into the gas-circulating system.

There will be few locations in the United States where enough natural gas for production of hydrogen will be found in the vicinity of large coal deposits suitable for commercial coal hydrogenation. For most commerical operations, the hydrogen would be produced partly by re-forming the hydrocarbons of the tail gases with steam and the remainder by gasifying coal.

Considering that in commercial-size operations about 25 per cent of the estimated capital investment will be spent on hydrogen-manufacturing facilities and that coal is much cheaper than gas-generator coke, it is possible that the commercial success of coal hydrogenation, based on present-day technology, may depend to a large extent on the development of low-cost coal gasification.

The coal-hydrogenation process is quite versatile as to the type of coal suitable as raw material and the type of liquid fuels produced. Bituminous coals, subbituminous coals, and lignite may all be hydrogenated, and the ease of hydrogenation and percentage conversion increase in the order named. Also, a given plant may yield widely different products, depending on operating conditions and techniques. A plant designed for gasoline production could produce separately or simultaneously a jet fuel, a diesel fuel of 45-cetane number with a pour point below 0°F, a heavy distillate fuel oil boiling above 600°F, and a heavy residual fuel oil of the Bunker C type. These commodities may be produced in varying yields; and in so doing the total output of liquid fuels would be increased as compared with gasoline production only. The table on the following page shows some data on bituminous-coal hydrogenation products obtained in experimental units.

The demonstration-plant engineering design is complete, and the construction is nearing completion. The first full run, to be on Rock Springs, Wyo., coal, is contemplated early in 1949.

Coal hydrogenation has never been carried out in America on a demonstration-plant or commerical scale. In working out the details of the design and solving the construction problems, numerous brand-new technologic and manufacturing problems were encountered. Tubing, flanging, fitting, and valving standards were set up for 10,000 psi working pressure, using different materials for three different temperature groups, ranging from at-

	Motor gasoline	Aviation gasoline	Jet fuel	Diesel fuel
Viscosity, °API	51	54	35	32
Boiling range, °F	95–350	105–320	320–570	350–600
Aromatics, per cent	45	43		
Naphthenes, per cent	35	35		
Paraffins, per cent	18	20		
Olefins, per cent	2	2	Below 3	Below 3
Sulfur, per cent	Below 0.05	Below 0.02	Below 0.1	Below 0.1
Octane No. M.M.	78	80		
Octane No. M.M. + 3 m. l., tel/gal	90	94		
Cetane No.				45
Reid vapor pressure, psi	10	7	Below 2	
Freezing point, °F	Below −76	Below −76	Below −76	Below −40

mospheric to 1000°F. Considerable trouble developed in fabricating, and American manufacturers developed new techniques and gained experience in rolling, forging, and machining.

By reference to best German practice, Bureau engineers were able to assist American manufacturers in designing such equipment as 10,000-psi paste pumps, heat exchangers, fired preheaters, and forged converters. Numerous improvements were developed in the demonstration-plant design, such as the superheated steam-jacketed paste preheater, flash distillation of the heavy-oil letdown with superheated steam, and added instrumentation for regulating liquid levels, flows, and pressures.

Operators experienced in processes at these temperatures and pressures were not obtainable. On-the-job plant training was out of the question, since the training had to proceed with the construction. The classroom methods developed and the training, operating, and safety manuals prepared are considered to be a real contribution and should be of value in training personnel for commercial-size coal-hydrogenation units.

Coal-gasification and Fischer-Tropsch Demonstration Plant. The coal-gasification plant comprises the oxygen-production unit, the coal-handling unit, the process-steam superheater, and the gasifier proper with its appurtenances. So far as is known, this is the largest pulverized coal-oxygen gasifier unit ever installed.

The oxygen plant is a 1 ton per hour Linde-Frankl unit, which was brought from Germany, where it had been operated for about four years. In one sense, it is rather a specialized plant in that it was equipped to produce some high-purity nitrogen, as well as oxygen of about 98.5 per cent purity. Other than this, it is the conventional Linde-Frankl plant and probably does not require any extended discussion here.

The coal-handling facilities are intended to dry run-of-mine coal and reduce it to approximately 200 mesh, after which it is conveyed pneumatically and stored in bulk hoppers, from which it is fed to the gasifier system. The crushing, drying, and grinding rate will be several times the gasifier requirements, so that this can be operated on the day shift only.

The steam for the process is superheated to reaction temperature in a natural-gas-fired pebble heater. The pebbles are fed to the top of the upper zone and move continuously down through it; countercurrent to the hot gases from combustion. The pebbles, heated to perhaps 3000°F, pass through a restricted neck into and down through the steam-superheating section, countercurrent to the steam. The pebbles are removed from the bottom of this zone at 500°F and transported in a bucket elevator to the top of the heating section and repeat the cycle. The steam temperature is an important variable in the gasification procedure, in that any heat deficiency in the incoming steam must be supplied by consumption of increased oxygen in the combustion of coal.

The gasifier proper is a modification and elaboration of the Totzek generator, partly developed by the Heinrich Koppers Co. in Germany before and during the war and described in several patent applications and "mission" reports. It is a refractory-lined steel shell 6½ ft in inside diameter by 9 ft in inside length. On either end are provisions for feeding superheated steam and the suspension of coal in oxygen. The steam enters directly from the pebble heater at temperatures as high as 2500°F, if desired.

Means are provided for maintaining the desired oxygen-coal ratio. The coal is fed from the hoppers to the point where it is picked up by the oxygen, and the suspension is carried from this point to the gasifier in pipes in which the velocity is maintained above the maximum rate of flame propagation for the oxygen-coal mixture. The fuel and oxygen are introduced through central nozzles. The steam is introduced separately in an annulus surrounding the coal nozzles.

After the reaction, the gases leave through a connection in the top center of the shell. Any ash particles too heavy to remain suspended fall into the dust legs and are removed. At the exit, the make gases are mixed with a quantity of cooled recycle synthesis gas.

In the demonstration plant at Louisiana, Mo., the design rates are a little over 2,300 lb per hour of coal, 2,000 lb (23,000 cu ft) per hour of oxygen, and about 2,900 lb per hour of superheated steam. This should lead to the production of about 90,000 std cu ft per hour of a raw synthesis gas containing 12 to 15 per cent carbon dioxide and between 40 and 45 per cent each of hydrogen and carbon monoxide. It has been stated that the proportion of hydrogen to carbon monoxide in the generated gas can be varied from 1.5 to 1.0 down to 0.7 to 1.0. Our present thoughts on the matter, however, are that a synthesis gas of the order of 1 part hydrogen to 1 of carbon monoxide will be desirable. At the outlet of the gasifier, a stream of cold recycle synthesis gas of about

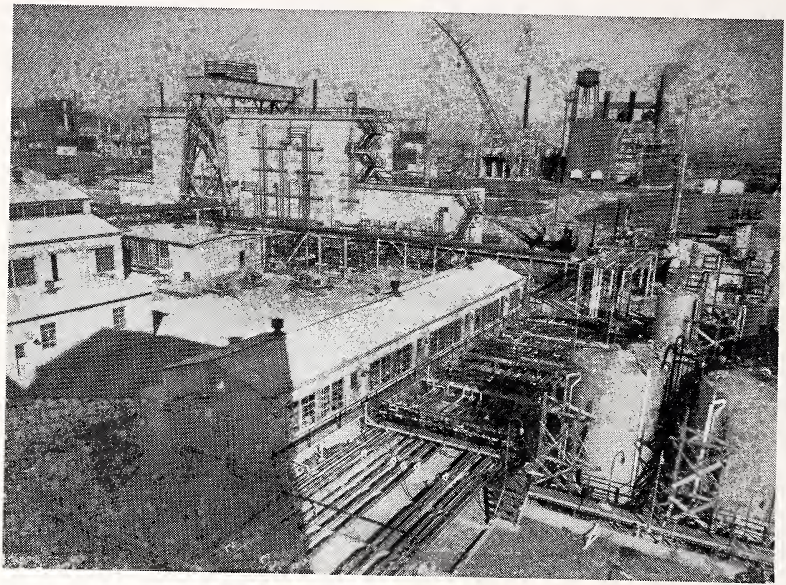

FIG. 62. Back of converter stalls at the Coal Hydrogenation Demonstration Plant of the Bureau of Mines at Louisiana, Mo. Buildings, left to right, are the high-pressure pump house, instrument house, and heavy-oil pump house. Former Missouri Ordnance Works in background. (*U.S. Bureau of Mines.*)

60,000 cu ft per hour is added to the effluent hot gases. The purpose of this addition is twofold. The primary object is safety. If some failure or upset occurs in the coal-feed mechanism, it would be possible to have an excess of oxygen still present at the outlet of the gasifier, which might present a serious hazard in subsequent operations. The recycle gas would provide, then, fuel with which to consume this excess oxygen, since at the exit temperature of approximately 2000°F ignition should be instantaneous. A second function of the recycle is to reduce quickly the temperature of the make gas. It is hoped that, in the gasifier, equilibria can be approached at temperatures of the order of 2000 to 2200°F. If this gas were cooled slowly, some further reactions undoubtedly could occur that would lead to production of increased quantities of compounds whose formation is favored by the lower temperature—carbon dioxide, for example. By adding the recycle gas, the temperature is reduced rapidly several hundred degrees and should minimize the undesirable low-temperature reactions. This reduction in temperature does not involve any loss in recoverable heat, since the recycle gas is raised to the temperature of the mixed stream. This total stream then passes through a waste-heat boiler, in which its temperature is reduced to perhaps 550°F, with the generation of about 4,000 lb per hour of high-pressure steam. Some fly ash will be removed at this point. The gas is then passed through a cyclone separator for further removal of fly ash and dust (about 75 per cent) and sent to a washer cooler.

The cooled gas leaving the washer cooler, containing probably less than 100 grains of ash per 100 cu ft, is picked up by an exhauster and part returned to the outlet of the gasifier as recycle; the rest is sent through two wet-flushing-type electrical dust precipitators in series, in which the final traces of dust are removed. A butterfly valve in the discharge of this exhauster is actuated by the suction pressure to control the pressure on the gasifier at ±0-in. water gage.

The cooled, dust-free gas is sent either to a 300,000-cu-ft storage holder floating on the line or to the suction of the synthesis-gas compressors. These are two-stage steam-driven reciprocating compressors designed to handle 90,000 st cu ft per hour, with a discharge pressure of 450 psi. Since the gas must be compressed for synthesis, it is economical to compress before removal of sulfur compounds so that the purification may be done under

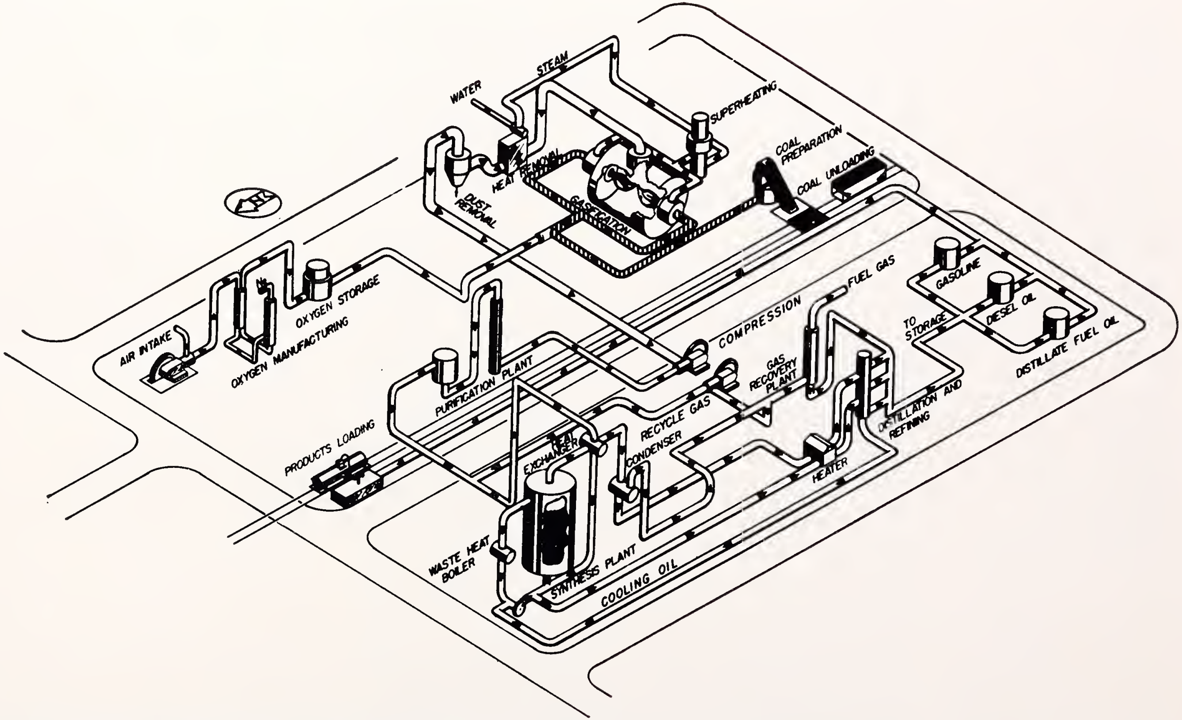

Fig. 63. Flow diagram of Bureau of Mines gas-synthesis demonstration plant, near Louisiana, Mo. (*U.S. Bureau of Mines.*)

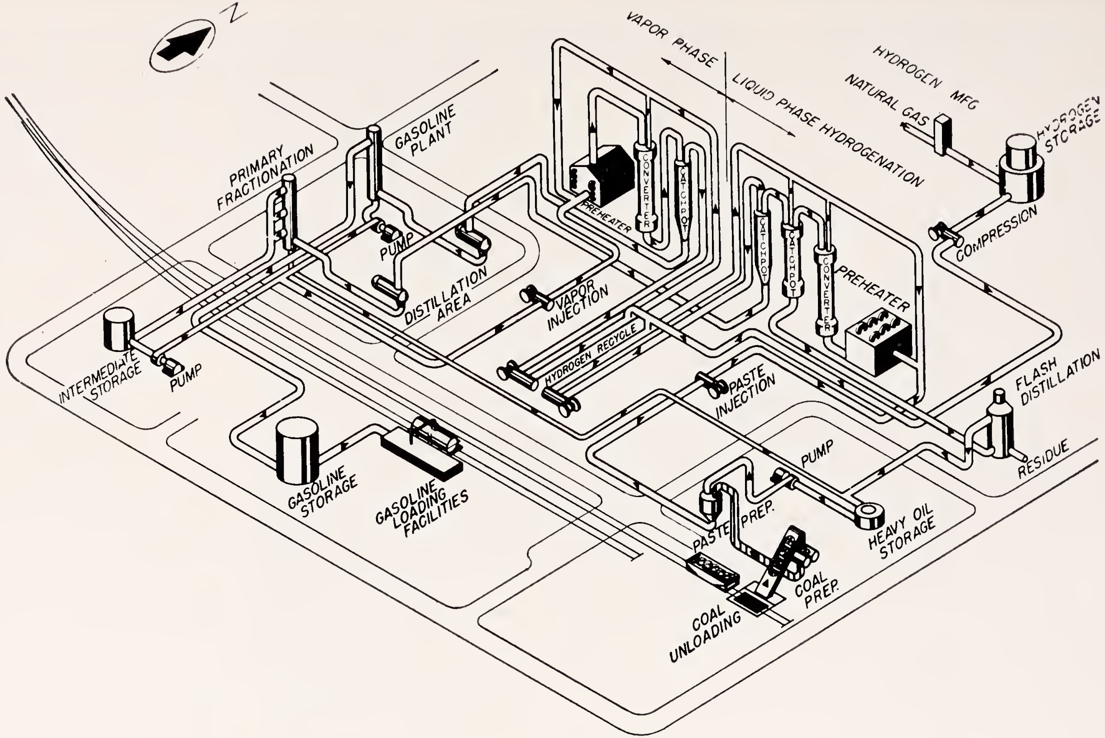

Fig. 64. Flow diagram of Bureau of Mines Coal Hydrogenation Demonstration Plant, near Louisiana, Mo. (*U.S. Bureau of Mines.*)

pressure. If a coal containing 3 per cent sulfur is used in the gasifier, the gas will contain about 520 grains per 100 cu ft of total sulfur compounds. At least 95 per cent of this probably will be present as hydrogen sulfide, with the balance existing as organic sulfur. In view of the high temperatures that will exist in the gasifier, the formation of large quantities of thiophene and other sulfur compounds of this nature probably will be minor. It is expected that the organic sulfur will be predominantly carbon oxysulfide and carbon disulfide. The bulk of the hydrogen sulfide will be removed by scrubbing under pressure with an ethanolamine solution. This unit is designed to reduce the hydrogen sulfide content to about 10 grains per 100 cu ft. The hydrogen sulfide recovered from the stripper may be vented or burned in this plant; but, of course, in any commercial unit sulfur recovery will be a necessity if only to eliminate the nuisance. Some credit to the operation may result from the sale of the sulfur or acid. The scrubbed gas then passes down through two iron-oxide towers in series for final cleanup of hydrogen sulfide. Because of the more rapid and thorough reaction of hydrogen sulfide with iron oxide under pressure, the residence time in these towers may be reduced well below that normally encountered in ordinary practice and the sulfur loading of the fouled oxide increased. It is planned to inject a small quantity of oxygen into the gas stream ahead of the oxide towers for continuous revivification in place. For purifying this flow of 2 million cubic feet per day, the total volume of oxide in the two towers will be about 250 bu.

The gasification unit was sized on the basis of the oxygen plant available. To augment the supply of synthesis gas and to provide an effective means of making any desired adjustments in the synthesis-gas composition, there are provisions for adding, after the iron-oxide towers, up to 50,000 cu ft per hour of gas, from an existing catalytic natural-gas re-former at the Missouri Ordnance Works plant. This gas will be approximately 25 per cent CO in hydrogen. The combined stream will then pass through two beds of active carbon in series in which any thiophene, hydrocarbons, or gum formers that may be present are removed. Probably appreciable amounts of the carbon sulfides will also be adsorbed. These carbon beds are approximately of the same volume as the oxide towers. As a final purification step, the gas is heated to 300 to 400°F, passed through a bed of granular alkalized iron oxide, heated to 500 to 700°F, and passed through a second bed.

The function of this treatment is to convert any organic sulfur compounds still present to hydrogen sulfide and to absorb this hydrogen sulfide, together with any that may have passed the oxide towers. This complete sulfur removal is essential to successful operation of the synthesis step because any of the active catalysts known and available at present are extremely sensitive to sulfur poisoning. At this point then, we shall have a compressed, dust- and sulfur-free synthesis gas ready for admission to the converter.

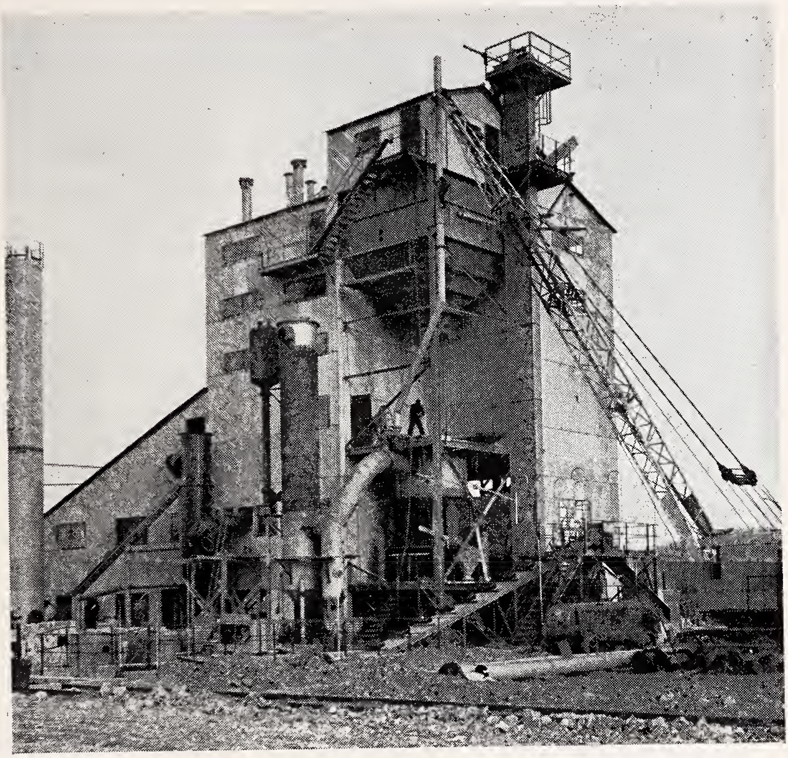

Fig. 65. Coal-gasification unit, shown under construction, will supply carbon monoxide and hydrogen—the raw materials for synthetic liquid fuels—to the Bureau of Mines Gas Synthesis (Fischer-Tropsch) Demonstration Plant at Louisiana, Mo. It is the largest unit ever installed to gasify pulverized coal with oxygen and superheated steam, and it will produce more than 2,000,000 cu ft of synthesis gas daily from 28 tons of coal. (*U.S. Bureau of Mines.*)

In the synthesis plant proper will be installed two types of converters that may be used alternatively to determine the relative merits of each. The first is that known as the "internally cooled" converter, developed by the Bureau of Mines group at Pittsburgh and Bruceton, in which a fixed bed of granular catalyst is submerged in coolant oil. The catalyst used in this step will probably be a fused synthetic ammonia catalyst of 2 to 6 mesh. The converter, about 5 ft in diameter with 25 ft depth, will hold about 40 tons of catalyst. The fresh-gas feed rate is designed for 300 volumes per hour per volume of catalyst space. The coolant oil is circulated up through the bed, cut, and through a waste-heat boiler to remove the heat of reaction from the catalyst. About 7000 Btu is liberated for each pound of product formed, and if the temperature rise on the coolant oil is held at 25°F, production of 80 bbl per day of product requires an oil-circulation rate of about 1,000 gal a minute to remove about 7 million Btu per hour. The purified synthesis gas is combined with a recycle gas in the ratio of 1:2 or 1:3, then passed through a heat exchanger and heated to approximately reaction temperature (500 to 600°F). The heated gas and the coolant oil pass together up through the catalyst bed and are separated in a drum at the outlet of the converter. The heated oil returns to the waste-heat boiler, and the gas passes through the feed heat exchanger and then into a water-cooled condenser. The liquid products condensed at this point are sent to storage or the distillation section after separation of the water formed in the reaction. The gas is, in part, recycled to the converter and the excess sent to the CO_2-removal and vapor-recovery system.

The other converter (nominal 40 bbl per day capacity) to be installed will contain a finely divided iron catalyst suspended in coolant oil. There will be provision for circulating this slurry within the reactor at the extremely high rate—about 3,000 gal per minute—to maintain the catalyst in suspension and allow a high rate of heat transfer to the steam-generating tubes submerged in the reaction space. As before, the gas is admitted to the bottom and flows up through the oil-catalyst slurry. The feed-gas heat exchange, the condensation of products, and the gas recycle are all comparable to those used in the ICC converter. In both instances, to eliminate from the system the high-boiling waxes formed, it is necessary to send a relatively small bleed stream from the coolant oil to the distillation system. Here the products, both heavy and light, are removed from the coolant oil, which is then returned to the synthesis converter. In the case of the slurry reactor, the suspended catalyst must be removed from this bleed stream before distillation, accomplished by centrifuges and filter presses. A small portion of the separated catalyst will be rejected and replaced by fresh material to maintain the activity of the system. The recovered catalyst and the new material added will be resuspended in clean coolant oil and pumped back into the system. There are two potential advantages to this slurry-type reactor. (1) Since a finely divided catalyst will be used and physical disintegration will not be an important problem, high mechanical strength will not be required. (2) Because the steam-generating tubes are within the reaction space itself, the high rate of external circulation of coolant oil to the waste-heat boiler is not required. The high-velocity agitation obtained in the converter can be accomplished with a low consumption of power. In the case of the ICC converter, the temperature of the bed will be regulated by the rate of flow of coolant oil and by the amount that by-passes the waste-heat boiler. In the slurry reactor, the temperature will be controlled by varying the pressure of steam in the generating tubes.

The recycle gas is used to maintain a more nearly constant composition of gas up through the catalyst bed as the conversion progresses and to provide for a more complete conversion. Both units are designed for and may be operated at pressures in the range of 300 to 600 psi and at temperatures up to about 600°F. It is a limitation on the process that, if operations at higher temperatures were attempted, it would probably be very difficult to find a coolant oil that would be heavy enough not to distill under these conditions and yet be stable enough so that thermal cracking would not be extensive.

The excess gases leaving the system will be scrubbed for the removal of carbon dioxide in an ethanolamine scrubber under approximately synthesis pressure. The carbon dioxide content of this stream will be in the neighborhood of 50 per cent, and even at a plant as small as this one the production of pure carbon dioxide will be about 40 tons per day. After a second scrubbing for the recovery of light hydrocarbons, the gas is sent to the plant fuel system.

The distillation section is designed to perform three important functions. The wax formed in the reactions must be removed from the coolant oil to avoid accumulations that might clog the pores of the catalyst and unduly increase the viscosity of the circulating oil. The light products and distillate fuels must be separated and recovered, and the coolant oil must be separated and the proper amount returned to the synthesis section.

In the description of the synthesis section, two streams were indicated as going to the distillation processes. The first was the coolant-oil bleed stream for purposes of cleanup and the second the condensed material separated from the synthesis tail gas. The coolant-oil bleed is taken through a heater into a vacuum flash still, where the waxes and associated materials are separated as residue and all recoverable distillate is taken overhead as vapors. After condensation, this material is returned to the converter. The liquid from the converter condenser is heated and is passed into the primary distillation column. From this column are recovered gasoline as an overhead product, diesel oil and heavy-distillate fuel oil as side streams, and additional coolant oil as the bottoms product. The diesel oil and heavy-distillate fuel-oil side streams are sent to storage for use directly or for further treatment. The unstabilized gasoline recovered as primary distillate is sent to a debutanizing column, where C_3 and C_4 hydrocarbons are removed. The stabilized gasoline is vaporized and passed hot over a bed of bauxite. This stream contains a fair amount of oxygenated compounds, such as alcohols, aldehydes, and organic acids. The unsaturated compounds present are almost entirely alpha mono-olefins. The bauxite treatment results in removal of the oxygen from the molecule and in shifting of the double bond toward the center of the molecule. Both changes result in increased stability and in higher octane number of the treated gasoline. About 95 per cent of the raw gasoline is recovered as finished product.

The C_3 and C_4 hydrocarbons recovered in the oil scrubber represent as much as 15 bbl per day and may be polymerized into high quality gasoline. The polymer product and the gasoline from the bauxite treatment are combined and sent to another column, which will produce a stable, sulfur-free gasoline of standard boiling-range specification and about 75 clear ASTM octane number.

The diesel-oil fraction recovered from the primary column will require treatment to improve its stability and ignition qualities.

No process for this treatment has yet been selected, pending the results of research and development work in this field.

The oxygen plant is completed and tested. Work on the gasification section is in progress, and the bulk of the engineering of the synthesis and distillation sections is finished. It is anticipated that a year from now the entire plant will be on stream.

Conclusion. This paper has described briefly the processes and the plants planned for operation by the Bureau of Mines and mentions the benefits expected to be derived. However, by the very fact that design and construction of these plants were initiated, benefits have already been achieved.

The time and efforts expended by Bureau engineers have been matched many times over by the engineering and development work done by suppliers of supplementary processes, fabricators of equipment, and the like. The results of this work are available generally to industry in the form of improved design, increased knowledge, and skill. Studies necessary to the engineering of the plants have pointed the way to improvements and to changes applicable to design of commercial units.

The detailed design necessary for constructing demonstration plants has provided a sounder basis for estimation of investment and operating costs and more precise evaluation of competitive processes.

The ultimate necessity for the production of synthetic liquid fuels is well understood. It is believed that operation of the demonstration plants will contribute to the early and sound development of such an industry in this country.

Chapter IX

CAPITAL EMPLOYED IN THE PETROLEUM INDUSTRY[1]

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What Are "Profits"?

Few business terms are less understood than "profits." The expression is often thought of as representing the funds left over after providing for all expenses and available in their entirety for removal from the business in the form of dividends. This is rarely true in ordinary times and entirely false in times of inflation.

The term "profits" is a popular expression, the technical counterpart of which is "net income." Net income, or profit, however, at best is an accounting interpretation or abstraction, not a reality or tangible quantity such as "cash in the till." According to accounting practice, it is determined by taking the total income received by an enterprise and deducting the operating expenses and taxes, and then subtracting an *estimate* of the extent to which the capital assets employed have been extinguished, *i.e.*, worn out and used up. The sum thus set aside out of the total cash produced is supposed to be sufficient to replace the facilities of the business so that it can continue as a going concern. It is obvious that the adequacy of the sum thus set aside for replacement determines the reality of the reported net income. It is equally clear that "profits," depending for their computation on an estimate, are themselves not an absolute quantity.

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[1] Based on a statement entitled "The Function of 'Profits' in the Petroleum Industry" before the Subcommittee on Business Profits of the Joint Committee on the Economic Report of the Congress of the United States, Dec. 9, 1948, and a "Financial Analysis of 30 Oil Companies for 1948," issued June 28, 1949.

Fundamental Principles Affecting "Profits"

There are four basic conditions which should be clearly held in mind by anyone seeking to analyze the size and significance of profits. I shall try to define these four principles and then briefly illustrate each point by data taken from our study of 30 oil companies.

1. In times of inflation, or rapid change in the purchasing power of the dollar, "profits" as reported on the basis of established accounting practice are in effect overstated by the amount of the rise in replacement costs over the sum set aside to cover capital extinguishments—depreciation, depletion, and the like.
2. In times of inflation, reported "profits" cannot properly be compared with previous years because of the shrinkage in the purchasing power of the dollar. Only by correcting for the changing length of the yardstick can this be done with any semblance of accuracy.
3. In times of inflation, the rate of return on the capital employed, ordinarily a very useful standard, cannot be used as a criterion of the magnitude of "profits" because the rate of return is a ratio between two sets of dollars of different values. It is a mathematical error to strike a ratio between things of a different kind. Only by adjusting either the capital employed or else the "profits" to like dollars is such a ratio permissive.
4. In all times, inflationary or normal, the most effective criterion to apply in the judgment of "profits" is their adequacy or inadequacy in the process of capital formation. Our entire economy is dependent upon the formation of sufficient capital funds to maintain and expand the country's productive capacity. As capital costs rise, "profits" are called upon to supply increasing amounts of these funds.

Reported "Profits" Are Overstated in Periods of Inflation

The reported net income of 30 oil companies was 763 million dollars in 1946 and 1,219 million dollars in 1947, an increase of 456 million dollars, or 60 per cent. On the face of it, this increase appears large. But the charges for capital extinguishments (depreciation, depletion, etc.), designed to recover the capital fund, extinguished during the year were inadequate to replace the physical counterpart of this capital at prevailing higher costs. "Profits" were therefore called upon to make up the discrepancy, and part of the reported total was diverted to this purpose. Thus "profits" computed by accounting procedure were larger than *de facto* profits. In other words, the *increased* cost of replacement appeared on the books as a profit.

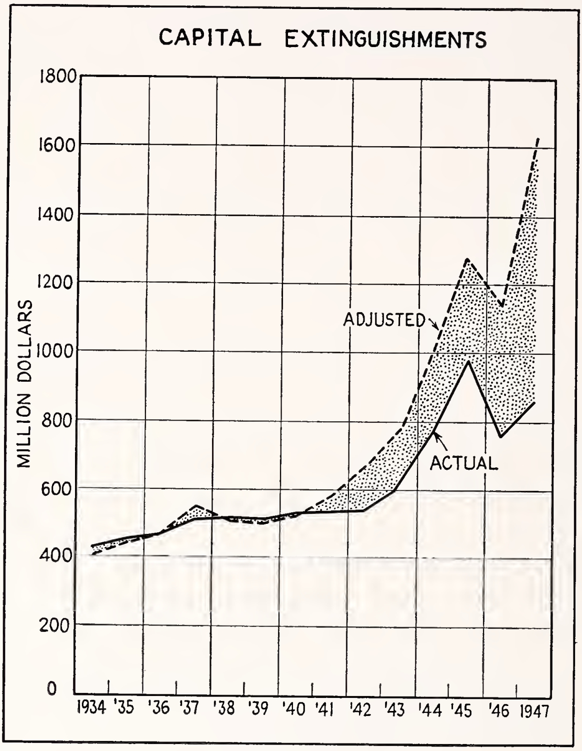

Fig. 66

The extent to which reported "profits" were thus in effect overstated can be approximately determined by adjusting the capital extinguishment charges, which are expressed in historical dollars, so that they reflect current dollars, or the cost of the physical capital to be replaced (see Fig. 66). If this is done,[2] we find that the adjusted net income[3] becomes 418 million dollars in 1946 and 509 million dollars in 1947,[4] an increase of 22 per cent. These figures are, respectively, 382 million dollars less and 767 million dollars less than the reported figures, which are accordingly magnified by inflation to the extent of 91 per cent in 1946 and 151 per cent in 1947. It thus becomes apparent that the changing value of the dollar distorts the income account so that the reported net income ceases to be synonymous with profit.

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[2] All adjustments presented in this statement are computed by means of well-known economic indices expressed in terms of 1935–1939 = 100 as a prewar base. The indices and computations are shown in Table 1.

The absorption of part of the reported net income by the higher costs of replacements is indicated by a 1947 rise in capital expenditures of 696 million dollars and by a decline in the percentage of net income paid to stockholders from 43.4 per cent in 1946 to 34.9 per cent in 1947. By way of comparison, this ratio was 66.3 per cent in 1938.

Reported "Profits" Cannot Properly Be Compared with Previous Years

All financial transactions are ordinarily expressed in monetary units. The dollar, of course, is our standard of value just as the yard is one of our standards of length. "Profits" are expressed in dollars. But these dollars are no longer the same from year to year; their purchasing power or value has changed. Thus it is not proper to say that the "profits" of 30 oil companies have increased from 763 million dollars in 1946 to 1,219 million dollars in 1947. One can say with propriety, however, that these "profits" increased from 763 million *1946 dollars* in 1946 to 1,219 million *1947 dollars* in 1947. This consideration suggests that a more correct view of the change in "profits" can be gained if the dollars are adjusted to reflect the *same* purchasing power.

This adjustment can be made with a fair approach to accuracy by dividing the reported dollars by the Bureau of Labor Statistics Index of Wholesale Prices of All Commodities (see Fig. 67). If this is done, the adjusted net income, expressed in dollars of prewar purchasing power, becomes 509 million dollars in 1946 and 648 million dollars in 1947, the latter figure showing an increase of 139 million dollars, or 27 per cent, from 1946. Thus it is found that 33 per cent of the reported "profits" for 1946 and 47 per cent of the reported "profits" for 1947 were absorbed by the shrinkage in the value of the dollar.

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[3] These computations were made on the basis of net income before deducting minority interests' share.

[4] See the last two columns in Table 1 for a measure of the adjusted or real profits.

If this correction is not made in the reported figures, one finds himself comparing two different kinds of aggregates and falling into the same type of error as if he concluded that two bushels are twice as much as one ton.

Rate of Return an Erroneous Yardstick under Inflation

The rate of return on capital employed is ordinarily a useful and widely used measure of profits. It provides a true picture so long as the value of the dollar remains reasonably constant. It is computed by establishing the ratio of current net income to accumulated borrowed and invested capital, or invested capital alone. Since investments are made in the past and income is derived in the present, this ratio is obviously the relation of present dollars to past dollars. If the two sets of dollars are ap-

Table 1. Selected Financial Data of 30 Oil Companies Adjusted for Changes in Value of Dollar Years
1934 to 1948

Year	Indices used in adjusting data, 1935 to 1939 = 100				Net income, millions of dollars			Preferred and common dividends paid in cash, millions of dollars			
	Construction costs in 30 cities[1]	Cost of living[2]	Wholesale prices of all commodities[2]	Income retained after income taxes, per cent[3]	Reported	Adjusted to prewar dollars[4]	Amount (+) absorbed by decline in purchasing power	Actual	Retained after income taxes[5]	Retained adjusted for cost of living[6]	Absorbed by income taxes and rise in cost of living
1934	87	96	93	95.8	157	169	− 12	128	123	128	0
1935	87	98	99	95.8	254	257	− 3	120	115	117	3
1936	91	99	100	95.8	412	412	0	233	223	225	8
1937	107	103	107	95.8	573	536	+ 37	288	276	268	20
1938	107	101	98	95.8	300	306	− 6	199	191	189	10
1939	108	99	96	95.8	321	334	− 13	188	180	182	6
1940	110	100	98	94.7	377	385	− 8	209	198	198	11
1941	117	105	108	87.4	530	491	+ 39	251	219	209	42
1942	130	117	123	76.5	403	328	+ 75	221	169	144	77
1943	136	124	128	76.5	510	398	+112	242	185	149	93
1944	140	126	129	74.1	640	496	+144	288	213	169	119
1945	146	128	131	74.1	602	460	+142	291	216	169	122
1946	173	139	150	77.9	763	509	+254	331	258	186	145
1947	231	159	188	77.9	1,219	648	+571	425	331	208	217
1948	264	171	205	87.2	1,877	916	+961	471	411	240	231

TABLE 1. SELECTED FINANCIAL DATA OF 30 OIL COMPANIES ADJUSTED FOR CHANGES IN VALUE OF DOLLAR YEARS 1934 to 1948 (*Continued*)

Year	Capital expenditures, millions of dollars			Return on borrowed and invested capital, per cent		Capital extinguishment charges, millions of dollars				
	Actual	Adjusted to prewar costs[7]	Amount absorbed by rise in construction costs	Actual	Adjusted to prewar dollars[8]	Actual	Adjusted to current dollars[9]	Deficiency (—) in charges	Net income before deducting minority interests' share	
									Actual	Adjusted for deficiency in charges
1934	461	630	− 69	3.2	3.5	432	402	+ 30	181	211
1935	517	594	− 77	4.8	4.9	452	447	+ 5	280	285
1936	633	696	− 63	7.2	7.3	467	467	0	444	444
1937	927	866	+ 61	9.3	8.8	506	541	− 35	618	583
1938	668	624	+ 44	4.9	5.0	516	506	+ 10	335	345
1939	664	615	+ 49	5.1	5.3	515	494	+ 21	349	370
1940	656	596	+ 60	5.9	6.0	534	523	+ 11	402	413
1941	810	694	+ 118	7.9	7.4	538	581	− 43	560	517
1942	785	604	+ 181	6.0	5.0	542	667	− 125	426	301
1943	930	684	+ 246	7.3	5.8	608	778	− 170	538	368
1944	1,094	781	+ 313	8.7	6.9	776	1,001	− 225	678	453
1945	1,112	762	+ 350	7.9	6.2	976	1,279	− 303	640	337
1946	1,377	796	+ 581	9.3	6.5	763	1,145	− 382	800	418
1947	2,073	897	+1,176	13.2	7.7	872	1,639	− 767	1,276	509
1948	2,591	981	+1,610	17.3	9.9	1,109	2,273	−1,164	1,963	799

[1] American Appraisal Company.

[2] U.S. Bureau of Labor Statistics.

[3] U.S. Treasury Department: based on annual income of $10,000, married and one dependent.

[4] Reported net income divided by Index of Wholesale Prices of All Commodities.

[5] Actual dividend times per cent of income retained after income taxes.

[6] Portion retained after income taxes divided by Cost of Living Index.

[7] Actual capital expenditures divided by Index of Construction Costs.

[8] Based on yearly change in capital employed and actual earnings expressed in terms of Index of Wholesale Prices of All Commodities.

[9] Actual capital extinguishments multiplied by Index of Wholesale Prices of All Commodities.

proximately the same in value, all well and good. But if the two sets of dollars differ substantially, as they do when inflation intervenes, then not only is the ratio false, but one commits a mathematical error even in computing it. It is not permissive to strike a ratio between unlike things; for example, no one would undertake to say that profits of 1 million dollars made by an

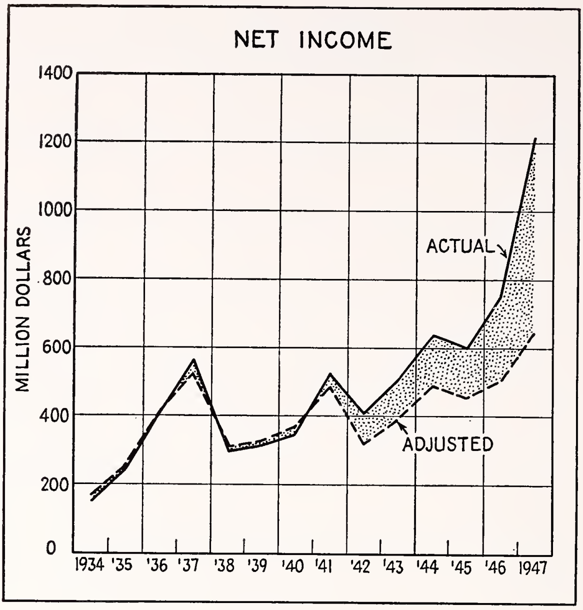

Fig. 67

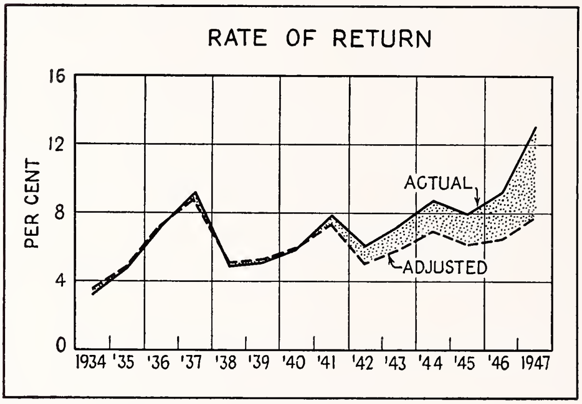

Fig. 68

enterprise which had a net investment of 10 million pounds sterling represented a rate of return of 10 per cent. He would first convert the dollars to pounds or else the pounds to dollars and then compute the ratio.

For the 30 oil companies in 1946 and 1947, the rate of return on borrowed and invested capital indicated by the *reported* figures rose from 9.3 to 13.2 per cent. But this computation is erroneous. The error, however, can be eliminated if the numerator and denominator of the ratio are expressed in like dollars. When this is done, the adjusted rate of return becomes 6.5 per cent for 1946 and 7.7 per cent for 1947 (see Fig. 68).

Relation of "Profits" to Capital Formation

Capital is a word with two meanings. It represents monetary funds which are held or expended, and it represents plant and facilities for which the expenditures are made. We refer to financial capital as "capital funds" and to physical capital as "plant and facilities."

Capital originates out of savings—production in excess of consumption. There is no other source. Savings may be made by productive units, such as corporations, and by individuals; and through the intervention of credit future savings can be transferred to the present.

Capital formation is the process whereby capital funds are accumulated and converted into physical capital. Economic progress depends largely upon the rate of capital formation, and therefore the process is indispensable to our standard of living. Measures which interfere with capital formation are harmful.

Let us examine the bearing of oil-company "profits" upon capital formation in the petroleum industry. We shall use the record of 30 oil companies for the illustrative figures.

In 1947, this group of oil companies generated cash out of its own operations to the extent of 2,160 million dollars. This sum was segregated by conventional accounting procedure into 1,219 million dollars of net income and 941 million dollars of depreciation, depletion, etc. The latter item represents an estimate of the capital worn out and used up during the year but was inadequate to replace this capital because costs had gone up. In addition, the group obtained 743 million dollars of outside funds, as follows: long-term debt issued, 476 million dollars; sales of common and preferred stock, 206 million dollars; and sales of assets, etc., 58 million dollars. Thus the group in 1947 generated and obtained 2,900 million dollars of funds.

What became of these funds?

By far the larger part, 2,073 million dollars, or 71 per cent, went into capital expenditures. Therefore, this amount represented physical capital formed. The remainder of the funds was disposed of as follows: 175 million dollars to working capital;[5] 197 million dollars to the retirement and refunding of debt; and 455 million dollars to stockholders and minority interests.

This analysis of the source and disposition of funds reveals the anatomy of capital formation in the petroleum industry. And the figures are all expressed in dollars of like vintage—1947 dollars—with one exception. The item of capital extinguishments is estimated on the basis of past dollars, and therefore part of the net income dollars must be allocated to this item to cover its conversion into physical replacement of the capital worn out and used up.

Some additional relationships are striking. The 2,073 million dollars of capital expenditures match closely the 2,160 million dollars of cash internally generated; and the same is true of the 455 million dollars of payments to stockholders and minority interests and the 476 million dollars of money borrowed. Does this mean that the group had to borrow the money to pay dividends? The accountant would certainly not admit this, for dividends can only be paid from surplus, but capital expenditures can be made from borrowed funds. But it is certain that without borrowings there would have been hardly any funds for dividends if capital expenditures had remained unchanged. And if capital expenditures had been less, the oil "shortage" would have been prolonged.

In view of these circumstances, it can scarcely be claimed that the earnings of the oil industry were "too great." The earnings played an essential role in the process of capital formation. Nor was too much capital formed in 1947. It can be stated with assurance that it was the magnitude of capital formation in 1947, and again in 1948, which has converted the petroleum situation from one of scarcity into one of abundance. What could be more important?

It may be observed in passing that the amount of capital expenditures was vastly inflated by the rise in construction costs. We have computed that 57 per cent, or 1,176 million dollars, out of total 1947 capital expenditures of 2,073 million dollars, was occasioned by the rise in costs, a penalty imposed by inflations. In prewar dollars, 796 million dollars would have done the same job (see Fig. 69).

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[5] The additions to working capital also represented capital formation, at least in large part.

If it is clear that oil "profits" play an important role in the essential process of capital formation, then the item of cash dividends to stockholders remains to be examined, for this amount passes out of the stream of corporate savings and into the hands of the public. Cash dividends for the group of 30 oil companies amounted to 331 million dollars in 1946 and 425 million dollars in 1947, an increase of 94 million dollars, or 28 per cent. These dividends, however, were in shrinking dollars. Correcting for income taxes and the changing value of the dollar, we find that

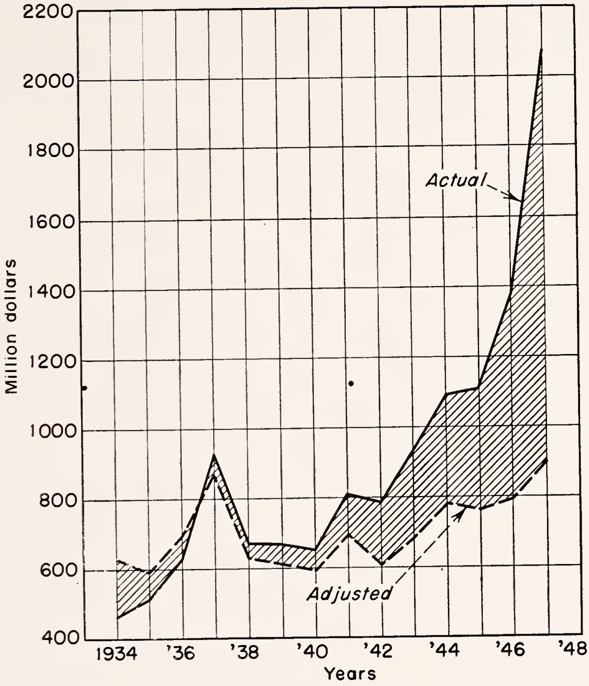

FIG. 69. Trend of actual expenditures for property, plant, and equipment of the 30 oil companies compared with adjusted figures expressed in prewar costs, by years, 1934 to 1947. The shaded area shows the impact of inflation. (See Table 1.)

the adjusted dividends retained were 186 million dollars in 1946 and 208 million dollars in 1947, an increase of 12 per cent. The 1947 adjusted figures are less than either the actual or similarly adjusted levels in 1936 and 1937 (see Fig. 70). The dividends, therefore, did not keep pace with the rise in the cost of living.

As the year 1947 drew toward its close, it became evident that the industry was to witness great difficulty in supplying the demands ahead and that the process of capital formation would be called upon to accelerate. It became evident then that oil "profits" would have an even larger job to do in 1948 than in 1947.

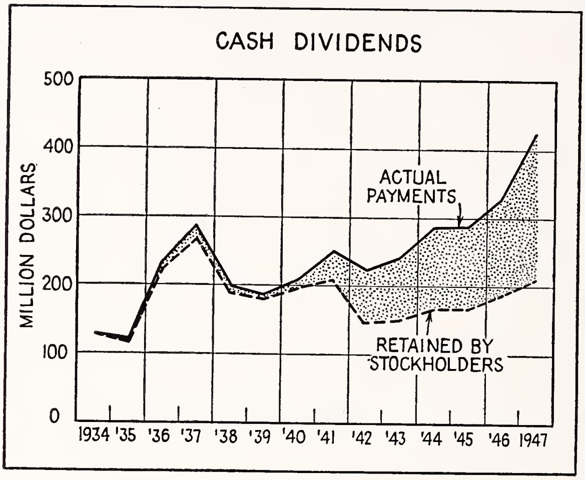

Fig. 70

Capital Formation for Replacement and Expansion

Several circumstances combine to make the capital needs of the petroleum industry exceptionally heavy, aside from the obvious one of inflated costs. In the first place, the industry is highly technological, which means that the capital investment per unit of output is large—several thousand dollars per daily barrel. In the second place, the petroleum industry is in a stage of vigorous growth requiring large investments for new facilities. Thus the industry must form capital, not only for replacement, but also for expansion.

The available data for the 30 oil companies do not permit a segregation of capital expenditures into those for replacement and those for expansion. Obviously the former vary less from period to period than do the latter, which are more cyclical. The demand for capital funds for expansion has been particularly large during the past two years, for the industry over that period had to meet an expansion in demand of over 15 per cent, or about 800,000 bbl per day.

For the economy as a whole, it has been estimated that about two-thirds of capital formation is for replacement and one-third for expansion. For the oil industry it is probable that the two categories have recently been more nearly equal. The need for capital funds for oil expansion may be expected to decline in the future, since the rate of growth in demand will probably decelerate, but by the same token the demands for replacement will increase as the industry becomes larger. On balance, however, the net effect will probably be some drop in the rate of capital formation, in which event "profits" may be expected to adjust themselves to a lower level of requirements.

"Profits" in 1948

Our analysis has thus far been confined to 1947 and previous years because adequate data are not yet available for 1948. However, reported oil "profits" for 1948 were substantially larger than in 1947. For example, the reported net income for the 30 oil companies amounted to 1,877 million dollars for 1948, an increase of 658 million dollars, or 54 per cent, over 1947 (see Table 2).

In keeping with the rise in net income in 1948, which is subject to all the qualifications outlined above, capital expenditures and additions to working capital were greater by 518 million and 274 million dollars, thus drawing off most of the increment and converting these funds into physical plant, equipment, and inventories. (For estimated expenditures for property, plant, and equipment see Table 3, and for estimated gross investment see Table 4.) The extent to which this process was essential can best be measured by the ratio of cash dividend disbursements to net income for the full year 1948. In 1948 only 25 per cent of reported net income was paid out in the form of cash dividends compared with 35 per cent in 1947 and 43 per cent in 1946. This drop in the rate of disbursements is indicative that the industry was "strapped" for cash in 1948 despite the magnitude of its income and that earnings were further converted into fixed assets.

It is fortunate that this was so. In 1947 we faced the prospects of a tight, if not short, oil supply. Late in 1948 and in 1949

Table 2. Financial and Operating Summary of 30 Oil Companies, 1947 and 1948, and Average for 1942 to 1946

	Average 1942 to 1946	1947	1948
Total income, millions of dollars	6,701*	10,483	14,165
Total costs and other deductions, millions of dollars	6,117*	9,264	12,288
Net income carried to surplus, millions of dollars	584	1,219	1,877
Net income, per cent of total income	8.7	11.6	13.2
Preferred and common dividends paid in cash	274	425	471
Dividends, per cent of net income, millions of dollars	46.9	34.9	25.1
Net assets, millions of dollars:			
United States	5,865	7,159	8,219
Foreign countries	844	1,365	1,853
Total	6,709	8,524	10,072
Current assets, millions of dollars	3,361	4,325	5,118
Current liabilities, millions of dollars	1,131	1,690	2,207
Net working capital, millions of dollars	2,230	2,635	2,911
Ratio of current assets to current liabilities	3.0	2.6	2.3
Capital expenditures, millions of dollars:			
Production	643	1,074	1,467
Transportation	121	297	300
Refining	210	402	562
Marketing	74	277	206
Others	12	23	56
Total	1,060	2,073	2,591
Production, per cent of total	60.7	51.8	56.6
Net investment in fixed assets, millions of dollars:			
Production	2,658	3,548	4,172
Transportation	721	979	1,200
Refining	1,037	1,278	1,717
Marketing	890	1,139	1,238
Others	113	125	162
Total	5,419	7,069	8,489
Production, per cent of total	49.0	50.2	49.2

* Gross operating income and costs have been adjusted to exclude sales and purchases under government directives.

TABLE 2. FINANCIAL AND OPERATING SUMMARY OF 30 OIL COMPANIES, 1947 AND 1948, AND AVERAGE FOR 1942 TO 1946 (*Continued*)

	Average 1942 to 1946	1947	1948
Borrowed capital, millions of dollars	1,082	1,437	1,758
Invested capital†, millions of dollars	7,168	9,054	10,631
Total, millions of dollars	8,250	10,491	12,389
Borrowed capital, per cent of total	13.1	13.7	14.2
Average borrowed and invested capital‡, millions of dollars	7,789	9,484	11,070
Net income§, millions of dollars	616	1,252	1,918
Return on borrowed and invested capital, per cent	7.9	13.2	17.3
Crude-oil production (net), thousands of barrels daily:			
United States	2,271	2,718	2,986
Foreign countries	453	700	780
Total	2,724	3,418	3,766
Crude runs to stills, thousands of barrels daily:			
United States	3,478	4,164	4,519
Foreign countries	462	603	644
Total	3,940	4,767	5,163

† Includes minority interests.
‡ Excludes minority interests.
§ Before deducting interest charges.

our tanks of oil were full, and supply was beginning to run ahead of demand. If this trend continues, the need for capital formation will become less insistent and the mechanism of the market will reduce profit margins and bring about a lower level of "profits." In this cycle, we have an almost perfect example of the function of "profits" in converting an economy of oil scarcity into one approaching abundance.

CONCLUSION

"Profits" may be likened to the motive power on a transcontinental train. On the plains, one locomotive is sufficient.

On the long upgrade in the mountains, two locomotives are required. And when the divide is passed, the second locomotive is dropped.

TABLE 3. ESTIMATED EXPENDITURES FOR PROPERTY, PLANT, AND EQUIPMENT BY THE PETROLEUM INDUSTRY IN THE UNITED STATES, CLASSIFIED BY DEPARTMENTS, YEARS 1947 AND 1948

Department	Millions of dollars		Distribution, per cent	
	1947	1948	1947	1948
Production*	1,400	1,725	56.0	59.5
Transportation	335	300	13.4	10.3
Refining	400	575	16.0	19.8
Marketing	300	225	12.0	7.8
Others	65	75	2.6	2.6
Total	2,500	2,900	100.0	100.0

* Includes intangible development costs of producing wells and dry holes.

Supply and demand correspond to the terrain. When they are in balance, the gradient is moderate. When they are out of phase, the gradient is steep. Inflation throws supply and demand badly out of balance and creates difficult country to be traversed. In the case of oil, inflation raised a mountain range. "Profits" are the means by which it could be surmounted. The 24 months

TABLE 4. ESTIMATED GROSS INVESTMENT IN PROPERTY, PLANT, AND EQUIPMENT OF THE PETROLEUM INDUSTRY IN THE UNITED STATES, CLASSIFIED BY DEPARTMENTS, DEC. 31, 1947 AND 1948

Department	Millions of dollars		Distribution, per cent	
	1947	1948	1947	1948
Production	10,425	11,525	53.2	53.1
Transportation	2,850	3,125	14.5	14.4
Refining	3,600	4,150	18.4	19.1
Marketing	2,475	2,600	12.6	12.0
Others	250	300	1.3	1.4
Total	19,600	21,700	100.0	100.0

of 1947 and 1948 represented a steep upgrade. "Profits," the motive power, were called upon to do an almost impossible job. By dint of their expansion, they succeeded. The divide was reached and is now being passed. Less motive power may now be needed. Only a renewal of the inflationary forces can interpose a new mountain range.

Chapter X

A CASE HISTORY OF OIL-SHORTAGE SCARES*

By LEONARD M. FANNING

Author, "The Rise of American Oil" and "American Oil Operations Abroad"

1. THE MODEL T SCARE—1916

On July 28, 1914, the First World War began. Irrespective of the military influence soon to be felt, this was a significant time in the history of petroleum. It was a time when licensed motor vehicles on the roads first broke the million mark.[1] Ford had launched his Model T a few years before—on Oct. 1, 1908, to be exact. This, the "rut climber," the "tin Lizzie," was first priced at $850. In 1909 Ford sold 10,000 of them. During the 1913 season, he sold 200,000 and, on Jan. 1, 1914, had his price down to $550.[2] Swiftly he was making good his boast to produce a car for the multitude.

Everyone wanted "gasoline buggies." They were past the "daredevil" and "society" stage. There was no question that gasoline was displacing kerosene as petroleum's first product. Within a three-year span, licensed automobiles had soared from half a million to almost 1½ million. The annual rate of production was running at half a million.[3] Where would it end? Where would the oil come from to supply such demand?

Another significant happening bearing on the petroleum situation of the day was the advent of the oil-burning naval vessel. Admiral Sir John Arbuthnot Fisher, First Sea Lord of the Admiralty from Oct. 21, 1904, to Jan. 25, 1910—"the period of his greatest activity and his preparation for a war with Germany"[4]—

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* Copyright, Leonard M. Fanning.

[1] *Automotive Ind.* (then *Automobile*), Jan. 9, 1913.

[2] *Automotive Ind.* (then *Automobile*), Jan. 1, 1914.

[3] *Oil Trade J.* (then *Fuel Oil J.*), November, 1915.

[4] FISHER, "Records."

declared so often fuel oil would mean 50 per cent added to the fleet's value that he was called "that oil maniac."[5] The trouble was Britain had no oil of her own except an old but vigorous Scottish shale-oil industry wholly inadequate for the huge requirements of the fleet.

It remained for Winston Churchill, who followed Fisher as First Lord of the Admiralty, to initiate the British naval oil policy. With Fisher's aid as chairman of the British Royal Commission on Oil and Oil Engines, which submitted a final memorandum (Mar. 3, 1913) to the effect that the Navy should, in the interest of speed and efficiency, fuel with oil, Churchill began the conversion of battleships. The oil had to come from abroad. Churchill conceived the principal source of this oil to be Persia (Iran), along with Burma and East and West Indian countries under British control or influence. On July 13, 1913, upon his recommendation,[6] the House of Commons approved the British government purchasing half of the 4 million pounds sterling Anglo-Persian Oil Company (Anglo-Iranian Oil Company) capital stock. When the First World War began, Britain was creating a division of fast battleships, capable by virtue of the use of fuel oil of 25 knots.

With less cause to worry about oil sources, the United States in the meantime had started to convert her battleships from coal to oil burning. Admiral George Dewey, hero of Manila Bay, in his capacity as President of the General Board of the United States Navy, in January, 1911, declared for naval fuel-oil stations,[7] and in April, 1911, Rear Admiral Cone, Chief of the Bureau of Steam Engineers, United States Navy, announced specifications of two new battleships calling for exclusive use of oil as fuel, also stating that all future specifications would be for oil.[8] Thus, at the outset of the war, oil burning was fairly launched by the navies of the Great Powers.

As navies converted to oil burning, so did the world's merchant marine. And the movement was accelerated by the war—by the tremendous shipbuilding programs, wherein new vessels were invariably oil burners. This bore direct relation to the enthusiasm with which new fuel-oil sources in Mexico and California—along with Persia—were opened up. British shipping interests endeavored to buy into several American oil-producing companies just before the war. Royal Dutch-Shell invaded the United States for the first time, entering California, in 1914. And the American Doheny interests in Mexico were soon to make huge contracts to furnish fuel oil to British maritime firms. Mexican and Californian oil was largely "heavy oil" of fuel-oil grade, adaptable for burning under boilers. Although torn by revolution, Mexico offered a great source of oil. Discoveries in California had made it our leading oil-producing state. But when the war started at the end of July, 1914, Oklahoma was challenging California with a great new field—Cushing—producing a "light oil," high in gasoline content.

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[5] Davenport, E. H., and Sidney Russell Cooke, "*The Oil Trusts and Anglo-American Relations*," New York, The Macmillan Company, 1924.

[6] Churchill, Winston, "*The World Crisis 1911–1914.*"

[7] *Natl. Petroleum News*, February, 1911.

[8] *Natl. Petroleum News*, May, 1911.

Thus, despite the new-found automobile and oil-burning ship, the petroleum business was experiencing a recession. As the saying went, it was feast or famine in the oil industry. Now it was "too much feast." The drill had discovered too much oil at one time for the market to absorb. The industry was feeling the concurrent development of new producing fields in Oklahoma, California, and Mexico.

That year—1914—the Cushing field in Oklahoma broke the oil market. It was the greatest pool of oil the world had ever known up to that time. Cushing was the event of the oil universe, a prolific source of high-grade oil, coming in with a rush. Cushing established Oklahoma as the premier oil state, rang in the great mid-continent oil-producing area, knocked into smithereens the prices of the East as well as of the West. Cushing, and Cushing alone, wrested from California the national championship and gave Oklahoma the distinction of yielding within her state boundaries more high-grade crude petroleum than was being produced in the rest of the world.[9]

Cushing added 36.5 million barrels to the Oklahoma-Kansas total of over 100 million barrels in 1914. Credit balance prices for Oklahoma-Kansas crude oil dropped from $1.05 to $0.55 a barrel, and great quantities of Cushing oil were sold in lump lots at $0.40. Purchasing companies and refineries feverishly built tanks to take care of the oversupply. More than 20 per cent of the 1914 yield went into storage unsold. At the same time, gasoline prices

[9] Moore, Prentiss T., *Oil Trade J.*, February, 1915.

dropped. The happy motorist was paying only 16 cents a gallon in New York. (No gasoline tax to boost his outlay in those days!)

Within less than a year this condition completely reversed itself. The feast was over. The great Cushing field began to decline in May, 1915. By October, the New York motorist was paying 21 cents for gasoline. Said a writer in *Oil Trade Journal* (then *Fuel Oil Journal*) of November: "Unless new sources of supply of light crude oil are discovered or a working substitute for gasoline in automobiles is found, the prices of both crude oil and gasoline, influenced by the inexorable law of supply and demand, are bound to advance rapidly in the next twelve months."

Staring the oil industry in the face was the official forecast of the National Automobile Chamber of Commerce (National Automobile Manufacturers Association) that motor-vehicle production for the 1915–1916 season (ending June 30) would go to over 1 million cars, compared with 700,000 the preceding like period. Licensed motor vehicles on the roads shot up to 2.1 million by the middle of 1915. New York State led the country with 22,000—an average of 1 for every 44 persons! The automobile clubs were growing anxious about gasoline supply and cost.[10]

Added to the plight of the petroleum refiner in meeting this demand was the popularity of the motor tractor on farms. Translated into gasoline, it was pointed out[3] that a gallon of the stuff would milk 300 cows, or bale 4 tons of hay, or mix 35 yards of cement, or move a ton truck 14 miles, or plow three-fifths of an acre, or make enough electricity to keep bright lights going in a farmhouse for 30 hours.

Another factor began to be felt—war demand. The British fleet had restored ocean commerce after the paralysis that came in the early months of the war, and the requirements of the Allies for gasoline and fuel and lubricating oils were shooting up our export totals.[10] Galician (Polish) oil fields were in the hands of the Kaiser; Rumanian oil exports, to all save the Central Powers, were closed by the British blockade of the Dardanelles. No Russian oil was exported. Russia needed all her own oil for military operations and besides could not pass Turkey's forts on the Bosporus. More and more the Allies turned to America to fill their petroleum needs. At the same time, the British Burmah Oil Company and the Royal Dutch–Shell increased their respective operations in

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[10] *Oil Trade J.*, February, 1916.

India and in the East Indies. And the Anglo-Persian Oil Company succeeded in establishing a respectable production in Persia (Iran), reaching an average of almost 10,000 bbl a day in 1915. (In 1918—the last year of the war—output averaged 23,600 bbl daily.)

While the United States dominated the world in oil production—we accounted for 65 per cent of the total, producing 777,000 bbl of the 1,186,000 bbl average daily world yield in 1915—the war stimulated international development. The statement was made that, if shipping could be secured, Mexico, producing 90,000 bbl daily in 1915, could triple her output. (In 1918, she produced 151,000 bbl; in 1921, she reached a peak of 549,000 bbl daily.) The great coming fields, where rivalry between American, British, and Dutch interests would be marked, were in South America, according to this prediction. A writer in *Oil Trade Journal* of February, 1916, went on to say:

"While it is true that opportunity favors companies of this country, where capital is unrestricted and plentiful, there is plenty of evidence that American supremacy will not go undisputed. If America is alive to its opportunities, it can also be said that other countries are alive to their needs. Europe's eyes are wide open to the future scope of the oil industry and to its own necessities. Britain's supremacy on the seas depends to no small degree upon her assurance of oil supplies. And England is not only thinking of the present, but of the future. Walter Runciman, president of the Board of Trade, during a debate in the House of Commons recently had this to say:

" 'The Board of Trade is looking ahead. We must ask the cooperation of our dominions; we must see that the control of the metals of the empire passes entirely from German hands; we must keep control of the world's coal; we must secure control of the supply of oil.'

"The uses and the need of petroleum and its products are increasing with a rapidity that has been beyond the conception of the most foresighted. Even the active drill has proved slow and refining capacity inadequate. The only answer is that other fields must be opened.

"The year will see intense rivalry between companies of this country and of Great Britain."

By early 1916 an oil-shortage scare—with all its "symptoms"—appeared. "Statesmen, automobile salesmen, government bureaus, and promoters, posing as financiers and economists" were giving the American petroleum industry a going over because of rising gasoline prices and demanding to know, "Is an oil shortage in the United States the real thing?" Answering the question, a writer in *Oil Trade Journal*, said:[11] "There is as yet no 'famine,' nor likely to be one for some time. Mexico is able to make good any shortage in the United States . . . . Mexican oil is not in the Oklahoma and Pennsylvania class, but it fills many gaps and will release more high-grade crude to be applied in the manufacture of high-grade products."

From Tulsa, Okla., one read[11]: "Forty cents a barrel on Aug. 1, 1915; $1.55 to $2.05 on Mar. 15, 1916—and the golden streams from the 34,000 oil wells of this part of the world are flowing broader and deeper and stronger every day! . . . The prices received for Oklahoma-Kansas crude are now much higher than ever before. How much higher will they go? . . . Too high prices of the raw material might react unfavorably . . . [and] users [of gasoline] might cut down their consumption."

One authority thought 30 to 35 cents retail was about as high as gasoline could go without beginning to hurt the motorist trade. Meanwhile, it was pointed out, Europe was glad to get all it could at 55 to 80 cents a gallon.

The petroleum industry could scarcely help being price-conscious. Sensationalism and politics seized on the oil-shortage scare. The Hearst newspapers, whose circulation had fattened on Standard Oil exposés during and following the antitrust suit and the recent dissolution decree, had Congressman Britten of Chicago introduce a resolution to levy a prohibitive export tax on gasoline, for the purpose of turning the gasoline exported into domestic trade to reduce the retail price.[12] Hearst's New York, Chicago, and California papers "whooped it up." "Every owner of a motorcar in New York City is with the *New York American* in its fight for cheaper gasoline," said the paper.

When Congressman Kitchin, chairman of the House Ways and Means Committee, ruled that the Britten resolution was unconstitutional, Britten introduced a resolution to amend the Constitution of the United States. Holland S. Reavis, editor-publisher of *Oil Trade Journal*, called them "gasoline statesmen." "The gasoline statesmen are sure having a hard time with their carburetors and spark plugs and magnetos," he said. "They seem to carbon up and produce no ignition."

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[11] *Oil Trade J.*, April, 1916.

[12] *Oil Trade J.*, May, 1916.

Senator McCumber asked the Secretary of the Interior to report on the high price of gasoline. In response to Senate resolutions, the Federal Trade Commission was investigating oil-industry prices and profits, and the Interstate Commerce Commission was engaged in a pipe-line inquiry. Gasoline price was sensationally debated, not only in Congress, but on the floor of many state legislatures, and attorneys general of several states were directed to investigate. *Oil Trade Journal* of May, 1916, lists the following as some of the measures proposed in Congress:

Congressman Steenerson of Minnesota—A bill giving the Federal Trade Commission authority over the oil industry with power to investigate and to fix the maximum price of crude oil, refined oil, and gasoline
Congressman Howard of Georgia—A bill for an embargo on exportation of petroleum products
Congressman Shallenberger of Nebraska—A resolution prohibiting the exportation of gasoline and all petroleum products
Congressman Bailey of Pennsylvania—A bill directing the Secretary of the Interior to sink wells in oil lands still held and owned by the Government and place the product in the open market
Congressman Treadway of Massachusetts—A resolution calling for the Attorney General to furnish data showing what prosecutions have been begun as a result of the high cost of gasoline

Congressman Howard startled the House with the prediction that gasoline for the use of the government itself in huge quantities would reach a wholesale price of 40 cents a gallon in the next two months. He based this on a talk with Secretary of Commerce Redfield, "who told him [the] contract price for government consumption last year was 11 cents."[13]

Congressman Steenerson said Government investigators reported the high prices of gasoline were due to artificial rather than economic means, and "yet the Department of Justice says it can find no sufficient evidence to warrant prosecutions under the antitrust laws." "Here, therefore," he concluded, "is an instance where the competitive system has failed to secure to the people reasonable prices of one of the prime necessities of life, and we must either submit to exploitation by monopoly prices or have prices fixed by authority of Congress. That Congress has the power cannot be questioned."

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[13] *Automotive Ind.*, Apr. 6, 1916.

It is to be noted that at this early date gasoline was being referred to as a "necessity."

Garnishing these bills was one by Senator Kenyon of Iowa, adopted by the Senate, providing for a comprehensive investigation of the Standard Oil Company and its subsidiaries, to discover if it were violating either the Supreme Court decree of dissolution or the Sherman antitrust law. A representative of the Standard Oil Company (New Jersey) promptly authorized the statement that the company would be glad to assist the government in any way to secure information that might settle all doubt, having confidence that no investigation could involve Standard Oil in violations of the Supreme Court decree.

Commenting editorially on these legislative measures, Reavis said:[12]

"These bills suggest action from the wide extremes of government purchase and operation of every oil field in the United States to regulation of every important interest engaged in producing, refining, transporting, and marketing crude petroleum and its products, particularly gasoline; and two high-gravity statesmen would prohibit the exportation of gasoline.

"All the measures may be included in the general statement that they are unwarranted, visionary, impracticable and in no instance would relieve the situation."

The automobile manufacturers became so panicky about a possible gasoline shortage and high prices that they proposed going into the oil business themselves. As a starter their executive organization officially declared for raising a fund of 10 million dollars to produce, refine, and distribute gasoline and other products to automobile owners, at a shade above cost, and incorporated a company.

"The agitation extends from coast to coast and from the Gulf of Mexico to Canada, embracing Federal and state governments, manufacturers, preachers, and individuals of high and low degree, rich and poor," Reavis continued. "Never before was there so much agitation in the press and Congress relating to one industry. The disturbance is purely atmospherical and will blow over, like April showers. Tender feeling may be hurt, and base sediment will be run into slush pits. Politicians, pikers, and automobile cranks are responsible for the crusade. The rabid talk is piffle and must necessarily fail . . . .

"The basis of the present attacks on the oil industry is the price of gasoline. Every refiner and marketer in the business knows that these attacks are unwarranted and unjustified, that they are born of ignorance or prejudice or both; and that the gasoline situation is one of the clearest instances on record of short supply of the raw material and long demand for the finished product.

"There is no question of Standard or Independent involved. Every interest engaged in oil marketing is the target. All are in the same boat. And all are being blamed for a condition over which they have no control—a shortage of high-grade crude petroleum, which is the source of the bulk of our gasoline supply."

The gasoline-price advances of the first half of 1916, which were chiefly responsible for the attack, took the tank-wagon (wholesale) price up to an average of 19 cents a gallon west of the Mississippi and 26 cents east of the same river. The retail price was anywhere from 2 to 3 cents a gallon higher.

One wonders what would have happened if this agitation had borne fruit to the extent of government interference with the economic processes of the industry. Soon we were to enter the war. Would we have been in as good a position at that time respecting petroleum had that occurred?

Dr. Van H. Manning, Director of the U.S. Bureau of Mines, predicting United States petroleum exhaustion within 27 years at the existing rate of production, used the "shortage" emergency to back the so-called Rittman "cracking" process. Incidentally, Rittman's invention never became a commercial success.[14] Discovery of cracking was bringing about its commercial development by numerous oil companies at this very time. Could the government have accomplished the revolution in refining actually then in progress within the industry?

Before the year was out commercially successful cracking processes, which greatly increased the yield of gasoline from crude oil, began to have their potent effect on gasoline supply. By September, the trade press was saying:[15] "A refiner who is in close touch with developments in the manufacturing end of the oil industry predicts that the processes already in successful use and those being perfected for the making of motor spirits will increase the production of motor fuel to a point where cost to the user will cease for a long time to come to be a subject of protest."

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[14] Dr. Walter F. Rittman, chemical engineer of the Bureau of Mines, resigned (Apr. 1, 1916) to head a company being formed for the purpose of manufacturing gasoline. *Automotive Ind.*, Apr. 6, 1916.

[15] *Oil Trade J.*, September, 1916.

Moreover, drilling campaigns by the industry under stimulation of high crude-oil prices resulted in discovery of more light and heavy oil in the mid-continent and California, which helped ease the tight gasoline situation. Both crude-oil and gasoline prices eased off. Oklahoma-Kansas crude oil was down to 90 cents in September–November, 1916. The strident cry for government regulation was no longer heard. When we entered the war Apr. 6, 1917, the Model T oil-shortage scare was over.

2. The Gasless Sunday Scare—1918

Our entrance into the war (Apr. 6, 1917) made certain a tremendously increased demand for American oil, both by us and by our comrades in arms. Could our supply, reinforced by Mexico's, stand the strain? Many people doubted it. So the Model T scare had no sooner disappeared than another incipient one began.

Warning cries were heard in Washington. Secretary Josephus Daniels, whose rapidly developing oil-burning Navy had been preparing for the apparently inevitable day, already had begun his advocacy of government oil operation to ensure a supply for it at low cost. He was backed by Senator Husting and a few other congressmen. They made a lot of "noise . . . about the government producing oil for the Navy."[16] A three-way battle was being waged between Daniels and two other members of President Wilson's Cabinet—Franklin K. Lane, Secretary of the Interior, and T. W. Gregory, Attorney General—as to executive privileges involved in the effort of Western legislators, backed by Lane, to get through Congress an Oil Land Leasing Bill returning areas withdrawn from the public domain to development. Immediately upon our declaration of war, the Oil Land Leasing Bill became a "war measure."

In a letter to Chairman Ferris of the House Public Lands Committee, dated Apr. 24, 1917 (18 days after our entrance into the war) Secretary Lane pointed out that the bill—identical with one that had passed the House, Sept. 23, 1914, and another adopted

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[16] *Oil Trade J.*, March, 1917.

Jan. 15, 1916, must be regarded "as an important measure for the utilization of the resources [herein] described, in time of peace, and as a measure of preparedness for war."[17]

"The existing state of war, in my opinion, renders the enactment of the bill necessary and vital," he wrote. ". . . The importance of ample supplies of gasoline and oil for the Navy, for airplanes, for motor trucks and other uses connected with successful prosecution of war can hardly be overestimated. . . . 6,491,145 acres of public land believed to contain oil are withdrawn from development. A part of this area is proven territory, in direct touch with pipe lines and refineries, and the products could be made immediately available by the enactment of this measure. I therefore earnestly recommend H.R. 3232 be enacted at the earliest practicable moment as a war measure."

Up to this time, the placer mining laws were the only ones that had been applied to oil development on the public domain. In 1897 Congress passed an act to this effect. It was the first law under which a claim for oil or gas could be "staked out." People went on the public domain in California and Wyoming in droves, made their locations, and on proof of discovery and payment of a nominal consideration received a patent to the fee title, free from any future claim or interest of the United States.[18] During the following decade hundreds made locations, surveyed their claims, marked the boundaries, recorded their notices, took possession of the land, and some commenced their development work.[19] Then in 1908, the U.S. Geological Survey, alarmed over shortage, unsuccessfully advocated withdrawing the entire public domain from oil location. In 1909, the Survey's advocacy of the same was for the opposite reason—oil overproduction. Suddenly, upon its recommendation that he act "to prevent waste," President Taft on Sept. 27, 1909, issued his famous orders withdrawing over 6 million acres of land in California, Wyoming, New Mexico, Utah, Idaho, and Colorado from entry because surveys showed them to be possibly oil-bearing.[20] There had followed years of oil plenty—and of effort to secure legislative relief for claimants affected by the withdrawal orders.

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[17] U.S. Public Lands Committee (House) Hearings, February, 1918.

[18] Mattei, A. C., Lands of the United States. "Our Oil Resources," Leonard M. Fanning, ed., 1st ed., McGraw-Hill Book Company, Inc., New York 1945.

[19] J. N. Gillett, U.S. Public Lands (House) Committee Hearings, February, 1918.

[20] *U.S. Geol. Survey Bull.* 623.

Leasing bills, as already stated, had passed the House in 1914 and 1916, only to fail on final passage. The leasing regulations proposed were similar to those pertaining to Indian and other government lands.[21] The government would retain title to the land and lease it only for drilling purposes. Twice also the Senate separately had passed leasing bills. Still the legislation languished. Daniels' interest was in those parts of the withdrawn lands known as the Naval Oil Reserves—Nos. 1 and 2 in California (Elk Hills) and No. 3 (Teapot Dome) in Wyoming adjacent to the Salt Creek field. While the Secretary of the Interior had jurisdiction over the public domain, the Secretary of the Navy had supervision over the naval reserves. Daniels jealously clung to his guardianship. Daniels and Gregory fought the opening of the public domain for oil development up to the time we entered the war. Now, because of the urgent demand for more petroleum, President Wilson "undoubtedly prevailed upon them" to withdraw their strenuous objections.[21] But Daniels stuck to his guns that the naval reserves must be excluded from any leasing bill and that any operation of them must be by the government for Navy account.[22]

Senator Myers, Chairman of the Senate Public Lands Committee, did not take kindly to the idea of the government oil operation of the public domain. It was "bad business for the government to obligate itself to spend millions in drilling many dry holes to secure a little oil for the Navy."[16] He cited the history of private production of oil and the development of wildcat acreage "to emphasize the almost certain loss of much money and time" and further stated the "unanswerable truth" that the Navy and Army could "buy all the petroleum they need," produced by private industry. Moreover, it was pointed out that government oil could not be developed fast enough to meet the war emergency.

That a world shortage of petroleum was likely at a time when the need was greatest was the subject of an extended review in the *Petroleum World* of London, May, 1917. This showed all foreign oil-producing countries either shut off from the Allies or failing to make big output gains—and the Allies forced to look to the United

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[21] *Oil Trade J.*, September, 1917.

[22] Commander N. H. Wright, U.S. Navy, before U.S. Public Lands (House) Committee Hearings, February, 1918.

States primarily and Mexico secondarily for their increased requirements. A writer in *Oil Trade Journal* of June, 1917, discussing the same subject, pointed out that neither was United States production reaching the expected total. With consumption pyramiding the "first stages of a world oil shortage" might arrive by the end of the summer, he said. He emphasized that enthusiastic automobilists were more responsible than war demand thus far, pointing out that, unlike European countries, civilian use of motor vehicles was unrestricted here. Now there were 4 million on the roads. They needed, according to Dr. William M. Burton, discoverer of the Burton cracking process (which was adding millions to the total gallons available) 2 billion gallons in 1917.

"Should an actual shortage of gasoline develop," said the trade journal writer, "it is possible that steps similar to those taken abroad will be necessary here to reduce the operation of motorcars by allotting gasoline supplies."

It was pointed out that shipping conditions—the world's lack of tankers—had a lot to do with the tight oil situation. Coastwise shipping was harrassed by German U-boats. Furthermore there was a shortage of tank cars. Rail transportation was demoralized. Scarcity of pipe for drilling purposes and for pipe-line construction was being felt. Crude-oil and gasoline prices were going up again. New York motorists who paid 13 cents in July, 1914, when the First World War started and when automobiles on the road were almost two-thirds fewer, now paid 26 cents a gallon. But the gasoline price advance was not out of line with other manufactured products such as steel, lead, coke, and electrolytic copper.[23]

"A threatened shortage," concluded the reviewer optimistically, "means an impetus to development work and to transportation and refining construction, or, in other words, a further great expansion of the American oil industry. There can be nothing discouraging in a condition of increasing consumption of oil as a necessity, with unlimited supplies of oil still untapped—and that is the crux of the whole situation."

As the oil industry mobilized for war, A. C. Bedford, president of the Standard Oil Company (New Jersey) and chairman of the Committee on Petroleum of the Advisory Commission of the Council of National Defense, in July, 1917, appealed to producers to find more oil. He said:[24] "Every oil producer in the country should be encouraged as a patriotic effort to secure the utmost possible output of crude oil. The present expense of drilling new wells is very great and increasing, and the results are often discouraging. But there is oil to be had if producers in the oil business will redouble their efforts to get it out of the ground."

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[23] *Oil Trade J.*, June, 1917.

In Kansas City, in October, he continued to strike this "keynote of the petroleum situation in America today." "We must bear in mind the fundamental difference between the nature of the problem of stimulating the production of crude oil and that of increasing the output of any other industry which is under the stress of supporting the government in this war," he said. "In the oil business the problem is not that of speeding up the production of existing wells. Their output is determined by natural conditions and can be affected to a very slight extent by men's efforts. The oil situation is unique because increased production can only be secured through drilling new wells. New enterprises must be undertaken and new capital enlisted."[25]

By going out and drilling new wells, American operators did succeed in increasing daily average production almost 100,000 bbl a day in 1917, reaching an all-time high of 918,600 bbl, compared with 821,700 bbl averaged in 1916 and 770,100 bbl in 1915.

Yet the crude-oil pinch was greater in January, 1918, than when we entered the war. Because enough new crude oil could not be had, refineries in Oklahoma and Kansas could not run at capacity.[26] Many new refineries had been built, and also pipe lines connecting them with fields that were expected to be greater producers. Where were they to get their throughput? Never had there been such activity in the oil fields. Never had there been so much wildcatting.

President Wilson had given Dr. Harry A. Garfield, Fuel Administrator, control over the coal industry under authority given the President by the Lever Food Control Act (passed Aug. 10, 1917), and when Garfield in January, 1918, announced an oil division with Mark L. Requa as Oil Administrator, it looked like government war regulation of the oil industry in the fashion exercised over coal and the railroads. This was especially true since oil supply was so tight and prices were rising. Washington advisers spoke of sweeping control of the oil industry, revision downward of prices, and the establishment of the "same jurisdiction over oil as now exists over coal."[27]

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[24] *Oil Trade J.*, August, 1917.

[25] *Oil Trade J.*, October, 1917.

[26] *Oil Trade J.*, January, 1918.

Previously, in December, 1917 the Petroleum War Service Committee of the Chamber of Commerce of the United States was formed with Bedford as chairman. It carried on to the end of the war as a voluntary organization of the whole American oil industry, cooperating with the government's war activities. Under the Lever act, the government had full authority in the matter of fuel oil and through that act could easily have taken over additional and full control of the industry during the war emergency. However, this was not found necessary, as the industry's organization, cooperating with the Oil Administrator, Requa, proved efficacious. Nevertheless, owing to the close race between supply and demand there were anxious times before the Armistice on Nov. 11, 1918, and victory.

Shortage talk grew louder. A measure of the growing scare is provided by testimony before the House Public Lands Committee in February, 1918, on the part of advocates of the Oil Land Leasing Bill, still awaiting action.[17] Thomas A. O'Donnell, president of California Petroleum Company and just appointed Oil Production Chief by Requa, said: "It is necessary for something to be done to untie these 6 million acres of land in the West; for us to get bids on [them]. If we have the resources out there, [it is necessary for us] to go to it, for the nation needs [the oil]." Verner Z. Reed, of Denver, representing Colorado and Wyoming interests, said: "I think those of us who are indulging in long harangues or long-drawn-out hearings or in speculative talk are really fiddling while Rome burns. . . . My figures, roundly, are that the demands for our country and for the Entente Allies, who are almost dependent on us, for the year 1918 will be about 400 million barrels of oil and that under existing conditions, operating all the oil that we can operate, putting every well into use that we have—the sealed wells in Salt Lake and the sealed wells in California along with the rest—we can produce about 340 million barrels of oil. Next to the menace of the lack of ships, a shortage of oil is the worst thing that can happen to us."

[27] *Oil Trade J.*, February, 1918.

Oil-burning railroads and fuel-oil-burning industries of the Pacific coast were threatened with stoppage because of oil dearth. The United States Navy became feverish over its supplies. Requa moved into the production picture by threatening to take action to increase the output of fuel oil by having the government order production in Naval Oil Reserve No. 2 in California, where litigation between the government and claimants was holding up agreement on legislation, to permit immediate production in the reserve.[28] He said he would recommend that the President commandeer the land under the Lever act and start production as a national emergency. Secretary Daniels previously had stated his willingness to open the reserves if a suitable bill could be agreed upon to protect the interests of the government and persons legally entitled to leases.

The oil crisis looked far worse to Secretary Lane in May, 1918, than it had in April, 1917, as he still urged passage of the leasing bill as a war measure. In another letter to Congressman Ferris of Oklahoma, chairman of the Public Lands Committee, he said:[29] "I trust you will press for immediate action upon the leasing bill. It is nothing less than a national war necessity that the supply of fuel on the Pacific coast be at once increased. I am in touch with the situation through the Geological Survey and the Bureau of Mines, and the facts before me justify the prophecy that within 60 days railroads, airplane factories, shipyards, and many industries will be unable to secure oil or fuel of any kind if a bill is not passed under which the producing lands will be open to the fullest development."

At this time, also, proposals were made that the government create vast aboveground storage gasoline and lubricating oils "against the oil industry not being able to find another Cushing field in the next year or two."[30]

Meantime, the first whisperings were heard of a considerable new oil source, springing from wildcatting over a large area under the stimulation of crude-oil price increases that had carried the basic Oklahoma-Kansas grade from $1.40 a barrel early in January, 1917, to $2.25 in March, 1918 (where the price was voluntarily pegged for the balance of the war under the influence of Oil Administrator Requa).[31] Spread out a map of Texas. Take a straightedge, allowing one end to rest on the Red River and the other on the Colorado River, and draw a line through the towns of Cisco and Coleman, and you have the backbone of the territory that was being heralded by geologists and petroleum operators. Further to localize this area, draw parallel lines 30 miles on each side of the first line, and you have the then mapped limits of the new "oil Eldorado" fairly well defined. It meant something like 15,000 sq miles, or 9.6 million acres where conditions were favorable geologically for the discovery of oil or gas. Comparatively speaking, this indicates a scope of prospective oil country larger than the four smallest states of the Union—Rhode Island, Delaware, Connecticut, and New Jersey. It could swallow up Massachusetts.

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[28] *The New York Times*, Apr. 28, 1918.

[29] *The New York Times*, May 5, 1918.

[30] *Natl. Petroleum News*, May 22, 1918.

Of course, no one claimed that all the territory within these limits would be found to be oil-bearing. "Some of it will be richer than other sections," A. J. Hazlett wrote in the *Oil Trade Journal* of February, 1918, "and there is plenty of room for several Cushings." Continuing, the writer said:

"At regularly recurring intervals in the quarter of a century that I have been following the ins and outs of the oil business there has always arisen the bugaboo of an approaching oil famine, with plenty of individuals ready to prove that the commercial supply of crude oil would become exhausted within a given time—usually only by a few years distant. But always about the time when it seemed as if their prophecies were about to be fulfilled, either a new pool would be discovered by some venturesome wildcatter or someone would come to the rescue with an invention that would help out wonderfully in its way. That is one reason why I cannot see any cause for alarm in the present pessimistic outpourings regarding potential petroleum possibilities.

"After Pennsylvania and the Eastern states came Ohio and the Middle West, and after the Middle West came Oklahoma and Kansas, and after Oklahoma and Kansas will come North Texas. After all the fields of the United States have been fully developed there remain vast unexplored regions in Canada, and after North America will come South America. After all the oil sands are gone, greater quantities are held in storage for future generations in the oil shales of the world. Before all these possible supplies shall have become exhausted, so far as we will know anything about it, the war will be over and there will be no cause to worry.

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[31] Requa on Record against Further Increases in Crude Oil Prices, *Oil Trade J.*, June, 1918. Stabilization of Crude Oil Prices, *Oil Trade J.*, August, 1918.

"When an oil famine was predicted four years ago, Cushing came to the rescue with a flood of high-grade crude petroleum and since then improved methods have enabled refiners to take out larger percentages of gasoline. Improvements in internal-combustion engines permit the use of kerosene and crude oil in many types of motors where formerly gasoline was required. Now that consumption has once again overtaken production, a new field looms big on the horizon and appears to have potential possibilities as much greater than Cushing as Cushing was greater than any development that preceded it."

In this territory, the greatest drilling campaign in the history of the petroleum industry went forward during the next 10 months. Nothing like it had ever been seen before. The town of Ranger in Eastland County was the center of the boom. Oil operators flocked to it from every section, sought leases, moved in their drilling equipment. The bonuses paid for leases reached record figures. It required a little time to prove up so vast an area. There were successes; there were great disappointments. The territory turned out to be more spotty than some had expected, but it fulfilled Hazlett's prophecy in many respects in the opening up of the great North Central Texas and North Texas producing fields. Although their influence on the crude-oil pinch did not begin to be felt immediately, they were definitely an easing factor before the German surrender.

With the summer, the question of gasoline abundance became a most critical one. How could we supply war requirements and at the same time keep driving our automobiles? By June 1, 1918, there were 5,462,000 motor vehicles in operation, over 650,000 more than on Dec. 31, 1917.[32] Oil Administrator Requa appealed to motorists to drive less and only for essential purposes as a patriotic voluntary sacrifice. No control was imposed—yet. Bad weather early in the year retarded the automobile season. Transportation conditions eased up so that the movement of petroleum products became much freer. This helped stave off a curtailment of civilian motorcar use although every other country at war and most neutrals banned nonessential driving.

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[32] *Oil Trade J.*, September, 1918.

Public sentiment was dead against such restriction, however. This was reflected in the attitude of the press—particularly the Hearst papers. Many government and state officials and legislative representatives held the same sentiment. While critical of high gasoline prices, they were either antagonistic or lukewarm when it came to the need of reducing civilian consumption. Both the Oil Administrator and the Petroleum War Service Committee were hesitant to invoke such control as it was recognized that "an arbitrary stoppage of the operation of so-called 'pleasure' cars would work inequalities and possibly great industrial hardship, experts estimating that probably 80 per cent of these vehicles are in utility operation."

Thanks to the "more or less unexpected increase in crude-oil production, which made possible a larger percentage increase in gasoline output than had been thought possible," and to the effectiveness of voluntary curtailment, arbitrary restriction was so far averted. The motorist in New York was paying only slightly more—26½ cents a gallon, ½ cent more—for gasoline in August, 1918, than when we entered the war. Prices were subject to Requa's sanction when the crude-oil stabilization plan (limiting premiums) went into effect that month, but sometimes they broke over at garages and filling stations, causing outcries by consumer and politician. Nevertheless, this was no anti-industry campaign such as the one accompanying the Model T shortage scare. The sober reality of war, the general realization that the oil industry was vital to Allied survival, precluded sensationalism. The question was: Would the industry succeed in its herculean effort to find the oil and to deliver oil products to the battlefronts and to industries and ships serving the war?

After conferences in Washington between automobile manufacturers and Bernard M. Baruch, Chairman of the War Industries Board, a decision was reached that for the last half of 1918 no manufacturer was to produce more than 25 per cent of the output of passenger (pleasure) cars made by him in the entire year of 1917.

By midsummer, the automobile demand for gasoline reached a crescendo. The railroads, jammed by the movement of war materials, could not handle the petroleum traffic necessary to meet market requirements. The auxiliary motor-vehicle traffic had to assume a greater load—and thus called for more gasoline. Increased vessel tonnage and the greatest export movement since we entered the war constituted another factor. Oil was going abroad at a record rate. Not only the needs of the Allies but those of a fighting American army in France—which only a few months before was scarcely more than a division—were being met. Another factor was a peak naval demand for gasoline for submarines and coastal patrol boats guarding against U-boat raids on this side of the Atlantic. And on the farms essential food supply hinged on greater use of gasoline-powered stationary engines and tractors.

All these demands, coming at the same time, combined to create such an immediately serious situation that Oil Administrator Requa on Aug. 27, 1918, issued his famous gasless Sunday request. It was not an order. He asked motorists, motorcyclists, and motorboat owners east of the Mississippi to exercise rigid economy in the consumption of gasoline for the next few weeks and to discontinue driving on Sundays to save gasoline.[32] Exceptions for doctors and other emergency and essential users were listed. His appeal follows in part:

"The United States Fuel Administration considers it necessary that a limited conservation of gasoline be undertaken in the states east of the Mississippi River, in view of the increasing demand for gasoline for war purposes and the paramount obligation of meeting promptly and fully all overseas requirements.

"An appeal is made, therefore, to the people of the United States east of the Mississippi River to exercise rigid economy in the consumption of gasoline during the next few weeks as a necessary and practical act of patriotism.

"War necessities are being and will continue to be promptly and fully met, but this is a period of the year when consumption of gasoline is at its highest, and the increased domestic demands, together with the extensive military operations in France, have rendered necessary for a limited period the adoption of safeguards against possible shortage.

"In view of the difficulty if not impossibility of differentiating between the various uses to which automobiles are applied, the United States Fuel Administration believes that the greatest measure of economy can be effected with the least interference to the business of the country through the discontinuance of the use of all classes of motor vehicles, motorboats, and motorcycles on Sundays.

"The United States Fuel Administration therefore requests that in sections of the United States east of the Mississippi River there shall be a discontinuance of the use of the vehicles above specified including all such as are operated for hire, on each Sunday hereafter until notification that the need for such discontinuance is ceased."

Chairman Bedford of the National Petroleum War Service Committee also issued a statement in which he expressed confidence that restrictions would not prove of long duration if the appeal was patriotically observed. He stressed the point, however, that there was "not at present enough gasoline for all war needs and all domestic purposes" and intimated that it might be found necessary to extend the restrictions to include the entire country.

The gasless Sunday request evoked anguished cries. Why was the East and not the West asked to sacrifice? Was there really a shortage, or just the fear of one? Senators hurled these and other questions at Fuel Administrator Garfield and Oil Administrator Requa. The Senate adopted a resolution offered by Senator Henry Cabot Lodge, the Elder, calling upon the Fuel Administration for data as to production, consumption, exportation, and reserve supply of gasoline. Lodge explained that he wanted to get at the reason for the gasless Sunday request. "But back of it there is a desire to ascertain whether reports are well founded that there is ample gasoline reserve supply in the country and that there is a purpose to put it upon the market later at the highest price that can be fixed."[33] Some Senators were quoted as labeling the appeal as an "unwarranted deprivation," based on information that gasoline supply was abundant.

Responding to the Lodge resolution, Fuel Administrator Garfield furnished data to the Senate showing that "a serious gasoline shortage exists." Figures revealed a daily deficit of 65,000 bbl a day, which would leave a reserve supply for only 30 days as of Aug. 31.[34] The controversy, involving judgment if not veracity, raged on. Actually, the request resulted in patriotic compliance and helped relieve the situation as to low-level stocks so that the immediate shortage crisis was averted. It was estimated that between 4 million and 6 million gallons of gasoline was saved the first gasless Sunday. Stricter adherence on subsequent Sundays brought the daily savings up to 8 million to 10 million gallons.[35] Total savings for the seven Sundays during which the request was in effect were estimated at some 60 million gallons.

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[33] *The New York Times*, Sept. 10, 1918.

[34] *The New York Times*, Sept. 12, 1918.

Was the gasless Sunday scare a phony? A writer in the *Oil Trade Journal* of October, 1918, says no: "The peak load of demand for gasoline, coming during the summer months and running into September, resulted in a shortage of supply which necessitated the Sunday 'gasless' day. That an acute scarcity of gasoline was possible, in view of the enormous increase in consumption largely for war purposes, had long been pointed out by government and oil-trade authorities, and perhaps the only surprising feature in the restrictive measure, to those who had been closely following events, was that it was so mild. The fact that the saving accomplished in this way was sufficient to bring about a material replenishment of stocks testifies not only to the patriotism of the car-owning public but also to the efficient efforts of the oil trade to meet the great requirements of the United States and Allied governments and the usual home-market demands."

Requa's rescinding of the gasless Sunday request—it lasted for seven Sundays from Sept. 1—did not mean that the industry was entirely out of the woods, that the shortage scare was over. Requa still pressed his conservation program.[35] In an address in New York on Sept. 28, he quoted Senator Barenger of France as saying: "For the conduct of hostilities to the mutual victory looked for with [by] the Allies of the West, oil is recognized today to be as necessary as blood. On the battlefield, on the land, on the sea, or in the air, a drop of petrol is equal to a drop of blood."

Requa continued: "This war cannot be won without the products of petroleum, and we all have a duty to perform in making those products available. Petroleum must be produced in adequate amount, must be transported, refined, and distributed to the consumer, and the consumer on his part must see that he uses petroleum products wisely and without waste. In no other way can we meet successfully the rapidly increasing demand both overseas and at home for the gasoline, kerosene, lubricating and fuel oils, so essential in the conduct of the war and in our own industrial life.

"It goes without saying that we will keep our own Army and Navy and the armies and navies of the Allies completely supplied. Our own wants must of necessity be supplied only after the petroleum products for the fighting men have been provided, and to that extent the petroleum industry must carry an additional burden that will be no light load. You who use these products can aid enormously in the successful accomplishment of the task, and I ask of you that you save wherever possible so that the full value of our supplies may be realized."

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[35] *Oil Trade J.*, October, 1918.

He said we would need, to meet only the normal increase in consumption, 365 million barrels in 1918, or about 70 per cent of the total production of the world and 25 million barrels more than in 1917. And yet that would not be enough, he declared, for during the past two years our production had been running less than consumption; our stored reserves, while still large, must be conserved. Our gasoline production increased over 8 million barrels the first half of 1918, yet had not kept pace with consumption, resulting in the drain on stocks. All demands for export had been met—and "will continue to be met." "To increase in a single year a business of the magnitude of the oil industry to the extent indicated," Requa said, "is not an easy task, and the increase that must be earned for in 1919 is still more difficult."

The race would be close. But on Nov. 11 the picture suddenly changed. The Armistice was signed. The war ended and with it the need for oil for military operations. The gasless Sunday scare was put away for keeps.

"Thanks to the Ranger field, I feel that we are assured of a very important new supply of oil in the immediate future," Requa said in October. Pipe lines with over 100,000 bbl daily were being completed into the North Central Texas area. The Ranger field not only helped clinch victory but promised relief from scarcity in the immediate future. A writer in the *Oil Trade Journal* of December said:

"It was recognized some time ago that if a new source of supply was not opened up, a crude-oil shortage would result which would eventually affect prices to the extent of materially damaging the competitive position of oil as against coal, as well as injuring the expanding gasoline and lubricating-oil markets.

"The need was especially felt for the uncovering of a new source of high-grade oil which could aid in meeting the tremendously growing demand for refined products. And while the need was immediate from the standpoint of the American oil industry clinching the victory for the United States and the Allies, it was also, in the broader sense, a need to take care of the future, to ensure this country's continued supremacy as an oil-producing territory, and mainly to bring about a general stabilization of the petroleum situation at a time when unprecedented factors were disturbing the natural law of supply and demand.

"Oilmen are now convinced that the field has been found in North Central Texas. Sufficient production has been taken out of the Ranger field already to credit it with having done its bit toward the winning of the war."

The war terminated before the passage of the Oil Land Leasing Bill, which did not become a law until Feb. 25, 1920. The 6 million acres of supposed oil-bearing lands, the opening of which had been so urgently advocated as an essential war measure, were still locked up. Yet, despite Secretary Lane's prophecy of Navy shortage, there was none, and Verner Reed's prediction of a maximum possible United States production of 340 million barrels in 1918 was exceeded by 15 million barrels and without opening up the sealed wells of the naval reserves in California and Wyoming.

3. The John Bull Scare—Ships and Security—1920

The war was won "on a wave of petroleum," said British Foreign Minister Lord Curzon of Kedelston at a London banquet to the members of the Inter-Allied Petroleum Council. Americal oil "and hardly any other" made up that wave.[36] Indeed, it might be said that the American petroleum industry was wined and dined for its war achievements, not only abroad but at home, and felt justly proud. The only blemish, so to speak, on its record of supplying all needs was the gasless Sunday restriction.[37] But that had been of short duration—had been removed well before the Armistice. There had been no actual oil shortage during the war's over 4½-year span. The Model T scare had not materialized. The gasless Sunday scare had died a-borning. The American oil industry had reason to preen itself.

Unfortunately, it was permitted no prolonged period of complacency. President Wilson's Secretary of the Navy, Josephus Daniels, soon was on the warpath for nationalization of oil to guarantee the Navy sufficient and cheap fuel oil, and in July, 1919, only eight months after the Armistice, Senator James D. Phelan of California rose in the Senate chamber to charge the British with trying to corner the world oil supply[36]. With our own oil "drained" in meeting war demand, we might find ourselves at the mercy of John Bull. Already there were signs of shortage, forcing Americans to pay higher prices for oil products. The legislator was followed by Senator Miles Poindexter of Washington, who introduced a resolution authorizing the Federal Trade Commission to investigate "recent increases on the Pacific coast." Enter the John Bull scare!

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[36] *Natl. Petroleum News,* July 30, 1919.

[37] All rules, regulations, and orders governing licensed units in the oil and natural-gas industries were vacated and set aside as of May 15, 1919, by the Fuel Administration. *Natl. Petroleum News,* May 21, 1919.

The Senate adopted the Poindexter resolution. The Commission was authorized to investigate the source and supply of oil in this country; also to inquire into "what corporate interests have conducted the production, refining, and marketing of oil in the last few years, and whether there have been any indications of illegal restraint of trade and unfair competition."

The controversy between government and claimants involving Naval Oil Reserve No. 1 in the Elk Hills field of California still raged on. The Oil Land Leasing Bill remained to be passed. Western congressmen pressed for its passage. They contended that oil from the public lands offered a solution to Pacific coast fuel-oil scarcity and a guarantee of sufficient supply for the United States Navy. Delay by Congress in acting favorably on the measure, Senator Walsh of Montana said, "is enriching the Standard Oil Company [of California] by millions of dollars," referring to the Elk Hills situation.[38]

Opposition developed, however, in the person of Senator Robert M. (Fighting Bob) La Follette, the Elder, of Wisconsin. He warned the Senate against undue haste in adopting the leasing legislation. He charged that the British government was behind one big oil company, which was "getting a hold" in America, meaning Royal Dutch-Shell, which during the war had extended its operations, through Shell Oil Company and Roxana Petroleum Corporation, into the major United States producing areas. Thus John Bull's program of world domination was not merely confined to foreign fields but included having for himself a considerable slice of our own oil fields—the most prolific in the world.

Government experts joined in sounding the alarm. Dr. Van H.

[38] *Natl. Petroleum News*, Aug. 20, 1919.

Manning, Director of the U.S. Bureau of Mines, said:[39] "In meeting the world's needs . . . the oil from the United States will continue to occupy a less and less dominant position, because within the next two to five years the oil fields of this country will reach their maximum production, and from that time on we will face an ever-increasing decline. We thus see domestic oil fields unable to meet our home demands under present methods of utilization and manufacture. This startling fact cannot be ignored."

Dr. George Otis Smith, Director of the U.S. Geological Survey, wondered whether, in the midst of our self-glorification in having supplied 80 per cent of the Allies' war demand, we might not find our world leadership in oil "more spectacular than safe."[40] Drastic action must be taken, he declared, to assure the United States of a future oil supply either by conserving home resources against foreign encroachment or by encouraging American capital to enter foreign fields, thus ensuring an additional supply for our needs. The latter offered the better solution, and the government should give its moral support to such undertakings, he held.

A tacit threat to foreign interests in the United States was implied by Dr. Smith when, soon after, he wrote:[41] "The open-door policy is best for America and the world. Encourage American capital to enter foreign fields, and protect foreign capital wherever invested in our country. However, the spirit of reciprocity does not require that the United States shall always keep its own door of opportunity open to the nationals of all nations, irrespective of their attitude to Americans in other parts of the world. The part our government should take in planning our future needs is to give moral support to every effort of American business to expand its circle of activity in oil production, so that it will be coextensive with the new field of American shipping. This may mean world-wide exploration, development, and producing companies, financed by United States capital, guided by American engineering, and safeguarded in policy because protected by the United States government. Thus only can our general welfare be promoted and the future supply of oil be assured for the United States."

In May, 1920, the U.S. Geological Survey predicted that the next generation of Americans would be forced to rely on more oil from abroad and synthetic fuels from shale oil and coal. It estimated only 7 billion barrels of oil left in the United States and Alaska, against 53 billion in foreign countries.[42]

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[39] *Natl. Petroleum News*, Oct. 29, 1919.

[40] *The New York Times*, Jan. 5, 1920.

[41] *Natl. Geographic Magazine*, February, 1920.

"Not counting oil to be obtained from shales and other retortable materials by distillation, the world's supply of recoverable petroleum amounts to as much as 60 billion barrels," the Survey reported. "Of this amount 43 billion barrels may be regarded as oil more or less definitely in sight as shown by actual drilling with successful results. The remainder covers the available oil which it is believed will be found in other regions in which oil seeps, asphalt deposits, or favorable geological conditions point to oil, although no producing wells have yet been drilled.

"Of this great amount, which is 13 times the oil already taken from the ground in America and about 9 times all the petroleum yet produced in the world, 7 billion barrels only, in round numbers, are believed to be left in the United States and Alaska, the remaining 53 billions being in foreign countries. This latter supply is nearly equally divided between the Old World and the New, the Americas having a total very close to that of the remaining continents. However, as in the case of coal, much more oil will be developed north of the equator than to the south.

"Fortunately, it is simply impossible to discover and take out the oil remaining in the ground in the United States, 7 billion barrels, in so short a period as 18 years. Instead of mining our petroleum so rapidly, we must either depend more and more on oil from other sources or get along with less oil. Our children will doubtless do both."

The postwar era was beginning to see a tremendous boom in civilian oil consumption—by motorcars, by oil-burning vessels and locomotives, by factories, and, with the advent of automatic heat, by a brand-new customer, the home. All competed, so to speak, with the military services, for although the war had ended and the world was weary of armed conflict, people of all nations were left with a highly developed sensitiveness for national defense. In the United States, the war lesson, that petroleum was a necessity, was too recently learned to be forgotten so soon, and the military mind thought of oil in new terms of security.

The Oil Land Leasing Bill was enacted Feb. 25, 1920. It gave the Secretary of the Interior the right to make leases with private companies and individuals on lands previously withdrawn from oil development. However, the Naval Oil Reserves remained under the aegis of the Secretary of the Navy and could be opened only at his discretion in a manner to his liking. Secretary Daniels had seen to that.

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[42] *The New York Times*, May 3, 1920.

Shortly after this action, the Secretaries of State, War, the Navy, and the Interior—constituting what was known as the Council of National Defense—were credited with a four-point action program to beat the oil shortage.[43] This program was as follows:

1. That the Secretary of the Interior buy all the oil produced on the Osage Indian Reservation in Oklahoma
2. That all the undeveloped oil lands in the Osage be converted into a naval reserve
3. That a globe-circling expedition of government oil specialists representing the Bureau of Standards, Bureau of Mines, Geological Survey, Shipping Board, and the Army and Navy be made, to report on the prospects of production in various oil fields not under the American flag, beginning with Mexico
4. That the government acquire lands in some of the foreign oil fields strictly for use of governmental departments in combating a possible future oil shortage in this country

Secretary of the Navy Daniels and Secretary of the Interior John Barton Payne (who had succeeded Franklin K. Lane in President Wilson's Cabinet) particularly became the watchdogs of our "oil security." In the early months of 1920 both the Navy and the Shipping Board had difficulty in getting bids for fuel oil. It was not easy to meet these requirements along with those of inflated civilian demands. Both the Navy and the Shipping Board were exercised over the problem of price. The Shipping Board was committed to a big program to build fuel-oil bunkering stations throughout the world, and to construct government-owned tank steamers to carry government oil to government-built oil-tank storage. Both the Navy and the Shipping Board reacted to the 1920 oil-consumption boom by manifesting serious anxiety over a possible oil shortage and our dependence in the future on foreign sources. How could we build a merchant marine without assured oil supply? Adm. W. S. Benson, Chairman, and Capt. Paul Foley,

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[43] *Natl. Petroleum News*, Mar. 17, 1920.

Director of Operations, United States Shipping Board, addressing the Marine Exposition at Grand Central Palace, New York City, warned of this country's absolute dependency on the development "by its own oil companies of petroleum resources in lands other than their own."[44]

Captain Foley urged two steps to correct the "present alarming conditions": (1) removal of excess-profits tax from profits derived by American oil companies from foreign drilling until capital investment there had been liquidated and (2) insistence by our government that the "same principle of equal opportunity now extended to British nationals in American producing fields be extended to American nationals in British producing fields." Failure to meet the situation, he declared, would mean that "control of the world's shipping must pass into the hands of our foreign competitors."

A report by the U.S. Geological Survey showing foreign countries using only half as much oil as the United States but having seven times as much oil in the ground lent fuel to the John Bull scare.[42] As the report phrased it, these nations were using about 200 million barrels of oil yearly, but they had resources large enough to last more than 250 years at the existing rate of consumption. In striking contrast was the supply picture of the United States. With an annual output of over 400 million barrels, we had only an 18-year reserve: in other words, we were using up our own supply 14 times as fast as the rest of the world.

The oil anxieties of both the Navy and the Shipping Board made headlines. The estimates of oil reserves made headlines. In this way, oil supply and the oil industry's ability to perform the task of finding sufficient petroleum became a matter of national concern. Whether it was the Navy in the newspapers at one moment or the merchant marine at another, the public sense of the national importance of oil supply grew. "It needed only a little propaganda to make the American people more oil-minded than the oilmen," is the way British commentators expressed it.

But the need of our State Department fighting for equal rights for American nationals in oil development abroad became evident with the assumption of mandates by Britain and France over Middle East petroliferous countries and, particularly, upon the signing of the San Remo Agreement of 1920. By its terms Britain and France divided between themselves the oil fields under British-French influence and in the mandated territories which had been taken from the Central Powers. Among them was Mesopotamia (Iraq), where oil had been discovered by the Turkish Petroleum Company.

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[44] *Natl. Petroleum News*, Apr. 21, 1920.

The general provisions of the San Remo Agreement seemed to bar the United States from participation and tended to confirm the talk of a British oil coup. It fed the John Bull scare.

"Almost hysterical outbursts" of Senators debating the Naval Appropriations Bill in May, 1920, served to "call attention to the near strangle hold the British government had on the undeveloped oil areas of the world."[45] Senator Phelan proposed the government organize a corporation, something like the Shipping Board's Emergency Fleet Corporation, to obtain oil for Americans in foreign lands. Through it the government "can operate as Great Britain operates through Royal Dutch–Shell, the Anglo-Persian, the Anglo-Egyptian, and the Alves Combination, not to mention the Pearson [Lord Cowdray] interests in Mexico." Secretary Payne told the California Senator he would be pleased to cooperate. Senator King, of Utah, said he would offer a resolution calling on Secretary Daniels to report to the Senate whether it was a good idea to have the government acquire oil lands in foreign countries for supplying oil to the American Navy. Also, how about including a provision in the Naval Appropriations Bill directing the Secretary of the Navy to "take possession of, all properties within the naval petroleum reserves . . . to conserve, develop, use, and operate the same, in his discretion, directly or by contract, lease, or otherwise, and to use, store, exchange, sell the oil and gas produced thereof?"

After changes in the Senate Public Lands Committee, the resolution was made to harmonize more closely with the Oil Land Leasing Act. Chairman Smoot of Utah called on the government to safeguard the national interests by seeing to it that, in the settlement of questions relating to the war, we were not excluded from outside oil sources "through the acts of any of the Allies or all of them put together."

Two weeks later, Phelan introduced a bill to incorporate the United States Oil Corporation.[46] This corporation would develop oil resources of foreign countries by exploration, refining, transporting, and storing through capital supplied by American oilmen and oil companies, but with the backing and sanction of the government. The government would have prior right to take any or all of the oil produced by the corporation on payment of the market price. The bill gave control to a board of nine directors appointed by the President. The corporation would have the right to solicit stock subscriptions and to organize subsidiaries. The theory was that American oilmen would be willing to furnish capital for an oil company promoted by the United States government; also that the government would use its diplomatic good offices to help the corporation obtain sources of oil in other countries.

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[45] *Natl. Petroleum News*, May 5, 1920.

[46] *Natl. Petroleum News*, May 19, 1920.

President Wilson's Secretary of State Bainbridge Colby pointed out objections to the proposed American government petroleum company.[47] He told Senator Phelan it seemed not unlikely that foreign nations might refuse such a company the right to carry on business. As against the argument of precedent in the British government's stock ownership in the Anglo-Persian Oil Company (Anglo-Iranian Oil Company), the question of the ethics and practicability of such government participation was debated on both sides of the Atlantic.

The oil industry fought shy of the proposed United States Oil Corporation. That was not the answer. Said the *National Petroleum News*[46]: "The answer is for the government to perform the functions that belong to it, and the American oil industry itself will take care of the foreign development. . . . The oil industry of America stands on its own feet and progresses by its own initiative, brains, finances, and daring."

Naïvely, it seems, one Sir Edward Mackay Edgar, intending only to bolster the fortitude of British investors, gave the oil-shortage scare all it needed in the United States to make it quite "wild." This spectacular British promoter, interviewed by the London *Times*, predicted that in 10 years Americans would be buying oil to the amount of 500 million barrels annually from British companies and paying at least $2 a barrel for it[46]. Earlier he had given the following as his candid opinion: "The Americans have dealt with their resources . . . in the pioneer spirit of sheer, unmitigated pillage. . . . They had recklessly squandered, and in 60 years run through, a legacy which, properly conserved, should have lasted . . . for at least a century and a half. . . . Just when the point has been reached that 'oil is king,' the United States finds her chief source of domestic supply beginning to dry up and a time approaching when instead of ruling the oil market of the world she will have to compete with other countries for her share of the crude product. . . . [Americans] find, almost wherever they turn, that British enterprise has been before them and that the control of all the most promising properties is in British hands."

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[47] Fanning, Leonard M., "American Oil Operations Abroad," McGraw-Hill Book Company, Inc., New York, 1947.

The anti-British Hearst newspapers found Sir Edward Mackay Edgar's statements to their liking. Anything about an oil-starved America versus an oil-abundant Britain made news and headlines in the American press generally, from this time until *finis* was written to the John Bull scare.

On May 12, 1920, the American ambassador to London, John W. Davis, presented a note to Lord Curzon, British Foreign Secretary, protesting against a policy of exclusion in Mesopotamia.[48] This note was the first of a long diplomatic correspondence initiated by Secretary of State Colby in which the United States demanded the privilege first of participating in discussions on the Mesopotamian concessions and then of sharing in the concessions. For a time the official British response resisted the American contention.

Injected into the picture was a demand for an embargo on oil shipped from the United States. Oil supplies from the United States to any country discriminating against American oil interests could be cut off at the discretion of the President, under a bill introduced by Senator Phelan.[49] Persons or firms violating a prohibitory order issued by the President would be subject to fines of $10,000. Secretary of the Navy Daniels gave his approval:[50] "I am in hearty accord with the provisions of the bill, and I am of the opinion that the enactment of this legislation is highly desirable." And from London was reported a "pronounced flurry" on the reading of Secretary Daniels's blessing on the legislation:[51] "If carried out it will have a far-reaching effect in this country, which imported 40 per cent of its petrol from the United States in 1919. There is a tendency to believe that it is connected with American dissatisfaction at British replies to date to America in contentions for an open-door policy in Mesopotamia."

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[48] Secretary Colby's note to Lord Curzon, *The New York Times*, May 13, 1920.

[49] *New York World*, Jan. 18, 1921.

[50] *New York World*, Feb. 2, 1921.

[51] *New York World*, Feb. 3, 1921.

As the Wilson Administration bowed out, the John Bull oil-shortage scare was at its height.

"For seven years it has been necessary for the Navy Department to be vigilant to prevent the exploitation of these reserves [the Naval Oil Reserves] by trespassers who had no legal right to the oil set aside for naval use," Secretary Daniels told a meeting of naval engineers in Washington.[52] "The long contest ended by legislation [the Oil Lands Leasing Act] at the last session of Congress, which more than recognized every equity. I have been compelled to fight almost every day of my incumbency in office to prevent the dummy entrymen and illegal operators from taking the Naval [Oil] Reserves, the only hope for the Navy when the all too rapid use of American oil will leave it the only available supply. Naval needs are paramount. . . .

"If the future oil supply is as small as many believe, why should not the government control the distribution of oil so as to ensure that its merchant marine and naval ships, practically all oil burners, shall never be found impotent because of the only fuel which can ensure their superiority? . . . Has not the time come when oil and coal and water power shall be nationalized and their ownership and distribution be regulated for the good of all and not permitted to be controlled by those who have not been free from profiteering? . . . Government regulations of the price of oil, coal, and water power should become as fixed a government policy as regulation of railroads, express, or telephone rates. It is indeed more important as to coal and oil because they are of limited supply and the world is threatened with the peril of their exhaustion."

Thus, the sturdy protector of the Naval Oil Reserves themed his swan song on ships and security, staying on his favorite strings —oil shortage and nationalization.

4. The John Bull Scare—"Oil Burning Politics"—1920 to 1923

The situation in 1920, 1921, and 1922 was that the oil industry of the United States faced an oil scarcity, actual or fancied. The motorists' multiplying appetite for gasoline, surmounted by the greatly increasing demand for fuel oil by ships, railroads, industries, and homes, challenged the oil producer to find enough of the raw material from which these products are derived. It was a scramble for crude oil.

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[52] *Natl. Petroleum News*, Dec. 29, 1920.

The industry was being swept along into the greatest era of expansion it had ever seen. Oil companies organized only a few years before were growing fast and big, bringing industrial fame to new figures—Harry Sinclair, Frank Phillips, J. S. (Josh) Cosden, W. S. (Bill) Skelly, to name but a few. Others were being formed in such number it was hard to keep up with them. Standard Oil, split into 33 parts in 1911, was getting the competition of its life not only from new-line independents but intermurally, so to speak. Standard Oil Company (New Jersey), former parent, and the separate entities were expanding, too, but percentagewise their refinery and market dominance was swiftly being reduced by the inroads of the independents. They were competing with each other for crude oil. Some were beginning to invade each other's marketing territory. Major companies were striving for self-sufficiency in the four integrals of petroleum activity—production, transportation, refining, and marketing. To most, this meant securing, if possible, their own crude-oil production. The search was hot—furious.

On Mar. 1, 1920, Oklahoma-Kansas (mid-continent) crude reached $3.50 a barrel, the highest price since the motorcar became a factor in consumption. It stayed there for almost a year—until Jan. 24, 1921. It has never reached as high a price since. With the development of Ranger, Burkburnett, and Mexia in North and North Central Texas, Burbank on the Osage Indian Reservation in Oklahoma, and El Dorado in Arkansas, the industry seemingly overtook consumption in 1921, when crude dropped to $1 a barrel, only to find the pinch on again by the end of the year, when the price advanced once more—to $2 on Nov. 7. By August, 1922, it was down to $1.25; by Feb. 17, 1923, back to $2 again. The drop in 1922 was largely due to the bringing in of the great Los Angeles basin fields in California.

Meantime, there was no letup to the John Bull scare. And high prices, of course, served to accent shortage or impending shortage. A concerned trade journal asked in 1920, "Will gasoline be rationed in 1921?"[53] *The Remount*, organ of the horse trade, predicted the "return of the horse" in 15 or 20 years, "when the supply of gasoline is either gone or the price too high for a person of ordinary means."[54] A successful fight against the inclusion of an oil tariff in the Fordney tariff bill revolved around a viewpoint that an inward flow of foreign oils was absolutely necessary to bolster an "already rapidly disappearing oil supply" in this country.[55]

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[53] *Oil Weekly*, Dec. 18, 1920.

President Harding's Secretary of State Charles Evans Hughes, who succeeded Mr. Colby, continued the United States attacks on Allied mandates as invalid except when American assent was given. Said the *New York Herald* editorially:[56] "With another unqualified notice served on the Allies by Secretary of State Hughes that none of our interests and rights existing anywhere during the war can be disposed of by any other power, powers, or authority other than our own, it ought to be clear to the Allies, to the League of Nations, and to all others that the United States government means what it says. This country has not surrendered its rights and interests under certain arrangements made without our sanctions as to the island of Yap, the Mesopotamian oil fields, and similar matters."

Failure of American interests to secure a share in concessions in the Djambi oil fields in Netherlands India brought American State Department protests, this time directed at the Netherlands government. Public opinion was aroused by charges that Dutch interests were combined with British (in the Royal Dutch–Shell combine) to exclude Americans.

The competitive scramble for crude oil was not confined to the United States. Practically given a mandate by the government to find oil abroad because of threatened shortage at home, American oil companies—represented at the start of the war in only two foreign oil-producing countries, Rumania and Mexico—redoubled their outside activities.[57] In the nearby countries of Mexico, Venezuela, Colombia, Ecuador, and Argentina, many initiated new exploration and development programs. Over a score of American oil companies actually were producing in Mexico; as many secured concessions in Colombia and Venezuela.

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[54] *Remount*, Jan., 1921.

[55] *New York Herald*, July 1, 1921.

[56] *New York Herald* editorial, Hughes' Stand on Mandates, Apr. 7, 1921.

[57] Fanning, Leonard M., "American Oil Operations Abroad." McGraw-Hill Book Company, Inc., New York, 1947.

Geological expeditions were sent to Panama and Costa Rica and other Central and South American countries.

For a time an American company—International Barnsdall—actually operated in Soviet Russia's Baku field under a contract to drill and produce oil. Another near-penetration of Russia was made by Sinclair Oil, which obtained an oil concession on the island of Sakhalin, lying off Siberia. The same company secured a large concession in Angola, in Portuguese West Africa. Another American company received a grant to prospect and operate in Abyssinia; another in Siam; another in Palestine.

The search was spurred by a continuous shortage-scare drumfire. Two great Mexican oil gushers went to salt water in 1919 and 1920, and even as the Golden Lane broke new production records in succeeding years with American oil companies leading the parade, geologists exchanged views as to whether Mexico was "through." If so, what effect would the resultant additional burden have on United States oil supply? In this discussion, the emphasis was on our future heavy dependence on foreign oil—and on synthetic fuels from shale or substitute alcohol from grain for motor fuel.

David White, chief geologist of the U. S. Geological Survey, at the Engineering Congress of the Petroleum Industry in Kansas City, said:[58] "Collapse or, better, a great slump in Mexican production, which seems sooner or later inevitable, can hardly fail to react on our own oil-field production, probably driving it to the limit; and it is likely that in the early period of this strain annual output of petroleum in the United States will pass its peak. Beyond this point our need for more foreign oil is likely to spring from our decreasing domestic production more than from further growth of our consumption requirements. In this period relief must come from other foreign oil fields and from production by distillation of shale oil, on whose adequacy and on whose yet undetermined cost we may be obliged to rely for protection against transoceanic importation at transoceanic prices beyond our control."

A joint committee composed of members of the American Association of Petroleum Geologists and of the U. S. Geological Survey in January, 1922, estimated United States reserves of 9 billion barrels of oil recoverable by methods then in use, enough to satisfy then present requirements of the United States "for only 20 years if the oil could be taken out of the ground as fast as it was wanted."[59] Should these estimates fall even so much as a billion barrels short of actual recovery, that error of 22 per cent would be equivalent to 4 years' supply, it was pointed out.

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[58] *Eng. Mining J.*, Mar. 18, 1922.

On the other hand, there were those who did not share the oil-shortage fear. Thomas A. O'Donnell, president of the American Petroleum Institute, found behind the dire predictions, honest miscalculation, intentional propaganda, and sensationalism.[60]

"We still have with us a rather overproduction of superscientists who are constantly measuring the petroleum resources of the world and point out various kinds of disaster following its exhaustion within a very few years," he said. "We also have some very able writers with a great command of the English language and a free use of mathematics who by using the statements of our scientists as a basis are writing some wonderfully interesting articles, some, no doubt, merely for the purpose of interesting the public, and others as a propaganda to create prejudice against some of the foreign nations. In any event, to say the least, it gives an exaggerated viewpoint in the public mind as to the immediate danger confronting the country through lack of the necessary petroleum resources of the future.

"While not overlooking the immeasurable possibilities of the requirements of the future, I have not changed my views during the last year to the effect that the predictions of exhaustion frequently made by well-meaning and conscientious scientists are grossly exaggerated and misleading, and while I can quite readily agree that the consumption of petroleum in this country may increase to a volume beyond all possibility of being supplied from our own resources, I would not consider a failure to supply the entire demand as a menace to our industrial life."

In an article in *Lloyd's List*,[61] Sir Charles Greenway, chairman of the Anglo-Persian Oil Company, said: "One does not need to be a prophet to foresee that the oil industry will continue on the road of prosperity and development. The world is only now beginning to find out manifold uses to which it can economically put this most adaptable of its subterranean resources, and every day brings to light new demands for liquid fuel. Talk about approaching exhaustion of world's supplies of petroleum, which filled the press a few months ago, was unwarranted and untrue."

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[59] *N. Y. J. Commerce*, Jan. 18, 1922.

[60] *Proc. Ann. Meeting Am. Petroleum Inst.*, Dec. 6, 7, 8, 1921.

[61] Quoted in *Investment Bull.*, Henry L. Doherty & Company, Jan. 21, 1922.

Perhaps, also, this is the place to make a belated recording of the words of an unsung prophet. Merle Woodson, formerly with the U.S. Geological Survey, which during this period was so pessimistic about our oil reserves, wrote in the *California Oil World*:[62] "In spite of the weight of opinion against me, I want to go on record with earnest prediction that there will not be a crude-oil famine in the United States within the next 20 years. I am going further; I want to make the prediction that there will not be a crude-oil famine in the United States within the next 50 years."

However naïve Sir Edward Mackay Edgar's original contribution to the John Bull scare, there could have been nothing but calculation (and cheer for British investors) in the interview he gave in December, 1922, after a visit in the United States, avidly printed by the Hearst newspapers.[63]

"In all the years I have known America I have never been so struck as during the past two months by her prodigality [in oil and metals]," he said. "Before long there will be a smash. An economic crisis is approaching. American demand for metals, cotton, and oil is so insatiable that a world-wide shortage in these commodities is inevitable. You can hardly name one of the big staples of industry which the Americans are not literally devouring. One hundred and fifteen million people are feverishly tearing from the earth its irreplaceable wealth, using it to maintain a rate of growth unprecedented in all human industry. . . . As for oil, America has already reached the importing stage. . . . Our business as Britons is to sit tight on what we have and exploit all the oil, cotton, and metal possibilities in the non-American world. In that way we shall do more than safeguard our position. We shall be able to supply America."

As for exclusion of foreign nationals from participation in United States oil development, demand for which was becoming more insistent in official and legislative circles, Walter C. Teagle, president of the Standard Oil Company (New Jersey), advised caution.[60] "It is to be hoped that the United States will never be forced to take such a step by way of self-defense," he said. "This country has always acted on the principle that petroleum, being one of the world's vital necessities, should be produced under such restrictions only as are essential to conserving the public's rights, these restrictions being applicable to citizens and to aliens alike. And as the United States, although having most at stake in the matter, has thus freely admitted the citizens of other countries to the advantages of its production, it is justified in asking now that its people be admitted to the development of the petroleum resources of other countries on the same terms as their citizens have been welcomed here."

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[62] *Calif. Oil World*, Feb. 9, 1922.

[63] *New York American*, Dec. 14, 1922.

At the same time, Sir John Cadman, of the Anglo-Persian Oil Company and chairman of the Inter-Allied Petroleum Council during the war, also spoke in favor of the open-door policy and denied as unfair the charge that Great Britain was "attempting to close any doors to honest enterprise."[60] It was the start of Sir John's efforts on behalf of an "oil entente." This entente was to be industrial, not political. It meant giving American oil companies a share in British-Dutch-French oil operations in mandated Middle East countries. But the John Bull scare had not yet run its course.

On Apr. 7, 1922, President Harding's Secretary of the Interior Albert Fall, blaming the Wilson Administration for big losses through failure to drill protective wells, announced a new Interior Department policy "to protect" Naval Oil Reserves Nos. 1 and 2 (Elk Hills) in California.[64] It was later revealed that under a Harding Executive Decree Fall's Department had taken over the administration of the naval reserves from the Navy Department.

On Apr. 14, Fall announced a definite policy of storing the Navy's crude-oil reserves in tanks above ground. Counter to the Wilson, Taft, and Roosevelt policy, it aroused immediate interest. On the following day the Senate adopted a resolution offered by Senator Kendrick asking the Secretaries of the Interior and Navy to inform the Senate if negotiations were in progress to lease the last of the naval reserves. Three days later Acting Secretary of the Interior Edward C. Finney turned over to the Senate a report that contracts for operating the Elk Hills reserves and Naval Reserve No. 3 (Teapot Dome) in Wyoming had been leased to private concerns. The Interior Department expressed the belief that oil was being drained off the Wyoming reserve just as it had been from the two reserves in California and that it was necessary to sink offset wells within the reserve to save the oil for the Navy.[65] The California reserves were leased to Edward L. Doheny's Pan American Petroleum & Transport Company; Teapot Dome, to Sinclair's Mammoth Oil Company. Heated debate followed in the Senate.

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[64] Senate Public Lands Leasing Proceedings, Senate Resolutions 282 and 294, 67th Cong.

Naval sentiment was reported mixed, many officers expressing themselves as opposed to private "exploitation." Rear Admiral J. K. Robinson, spokesman for the Navy in connection with the new policy, said sufficient oil would be stored in a year and a half as a result of the opening of the naval reserves.[66] Great quantities would be stored at Pearl Harbor and in Puget Sound, San Francisco, and, perhaps, Alaska. All high-ranking officers in the councils of Secretary of the Navy Edwin Denby approved the plan, he said.

Wilson adherents and conservationists attacked the leases. Former Secretary of the Navy Josephus Daniels uttered outraged cries.[67] Certain Wyoming oil interests attacked the Teapot Dome lease. Senator La Follette offered a resolution to get all the facts. Just previously he had asked for an investigation of the oil industry and gasoline prices for the years 1920, 1921, and 1922 by the Senate Manufacturers Committee, of which he was chairman.[68]

Secretary Denby defended the Teapot Dome lease on the ground that it was imperative to avert loss of oil by drainage. In June, Fall was personally submitting his report on the leases to President Harding. He sent a mail-truck load of documents to the Senate committee.[69] The President turned the Fall report over to the Senate, saying:[70] "I think it is only fair to say in this connection that the policy which has been adopted by the Secretary of the Navy and the Secretary of the Interior in dealing with these matters was submitted to me prior to the adoption thereof, and the policy decided upon and the subsequent acts have at all times had my entire approval."

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[65] *New York Herald, New York World,* Apr. 18, 1922.

[66] *Wall Street J.*, Apr. 21, 1922.

[67] *The New York Times*, Apr. 22, 1922.

[68] *Congressional Record,* Apr. 15, 1922.

[69] *New York Commercial,* June 8, 1922.

[70] *The New York Times,* June 8, 1922.

Senator La Follette's inquiry dropped Teapot Dome after the adoption of a resolution by Senator Thomas J. Walsh of Montana for an investigation of all government oil leases by the Committee on Public Lands, of which Senator Smoot of Utah was chairman. When that investigation was voted, Senator Walsh was named prosecutor and field surveys of the Teapot Dome lease began immediately, although it was not until Oct. 22, 1923, that hearings started.[71] So began what developed in the next few years into the Doheny and Teapot Dome oil scandals. In a sense, they were by-products of the John Bull shortage scare. At any rate, Fall justified his acts with regard to this affair on the ground of national oil security—the vital issue raised by the John Bull scare. Fall resigned as Secretary of the Interior early in 1923, but not before upsetting another precedent—excluding a foreign national from American oil development, another central issue of the John Bull scare.

When the Netherlands government confirmed the Djambi concession to the Bataafsche Petroleum Company, a subsidiary of the Royal Dutch–Shell Company, Congress had asked the Federal Trade Commission to investigate the whole subject of foreign ownership in the foreign and domestic oil industry. The Commission's report,[72] dated Feb. 12, 1923, showed the Royal Dutch interests controlling 11 per cent of the world's oil production and conditions of discrimination and exclusion against American interests in British, Dutch, and French territories.

The report detailed facts relating to the Royal Dutch–Shell combination, its universal sweep, including its holdings in the United States, its world-wide investments in oil concessions, refineries, and tankers, and stated that denial of reciprocity of treatment appeared to exist with respect to the petroleum industry of Australia, British Borneo, certain British African colonies, British Honduras, British Guiana and Trinidad, France and

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[71] *Wall Street J.*, Nov. 23, 1923.

[72] "Foreign Ownership in the Petroleum Industry, report of Federal Trade Commission, Feb. 12, 1923, to Senate Committee of Manufacturers, 67th Cong., 4th Sess., Government Printing Office, Washington, D.C., 1923.

French possessions, India, Italy, and the Netherlands and its dependencies.

A month after this report there was confirmation from Washington[73] that Secretary of the Interior Fall had denied the application of the Roxana Petroleum Company, a Royal Dutch subsidiary, for permission to lease oil lands of the Creek Indians in Oklahoma. The action was taken on the ground that the Netherlands government refused like or similar opportunity to American oil enterprise and because of the discriminations and burdens to which American oil interests were subject in various portions of the British Empire. This was one of the last decisions made by Mr. Fall before retiring as Secretary of the Interior, and he was quoted as considering it one of his most important acts.[74]

"For," he said, "this particular case is linked with and is a part of a gigantic movement, international in its nature, and charged by French writer Delaisi and others to be carried on with aid and assistance of certain foreign governments, to exhaust oil supplies of the United States while denying our explorers the right to prospect for oil elsewhere. This is charged to be to the end that a great oil monopoly shall be created in which Americans shall have no part."

Sir John Cadman again arose to deny that there was an anti-American oil combine, answering both Secretary Fall and the Federal Trade Commission.[75] "The difficulties in which American interests temporarily find themselves," said Sir John, "arise from their lateness in entering the list, the uncertain diplomatic support which they receive, and the delays which occurred in breaking fresh ground and in seeking new fields. Two-thirds of the earth's rock surface is of sufficient age to yield oil. Compared with the places where oil might be found as exploration continues, the concessions thus far taken represent hardly a scratch."

The twining and intertwining of international and national politics kept oil in the headlines throughout the 1920 to 1923 period. Thus, as to international politics, oil was an issue at the very start of the postwar period—at the Peace Conference in 1919; at the Disarmament Conference, for which our State

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[73] *Financial Times*, Mar. 8, 1923.

[74] *The New York Times*, Mar. 20, 1923.

[75] *New York Herald*, Mar. 23, 1923.

Department in 1921 made a comprehensive oil study;[76] at the Lausanne Near East Conferences in 1922 and 1923, which nearly failed because of the Mesopotamian problem, finally referred to the League of Nations.

The *New York World* in an editorial called it Oil Ueber Alles.[77] William Hard in the *Nation* called it Oil Burning Politics.[78]

As if it were not enough that oil was in the vortex of international politics, it must be a national political football at the same time. When La Follettee (in April, 1922) launched his gasoline-price investigation, the average gasoline price in the United States was around 23 cents a gallon, lower by 6½ cents than in January, 1921. While prices remained strong that summer, there were already evidences that discoveries of new oil fields would knock them down before very long. Nevertheless, La Follette persisted in his investigation, demanding detailed information from oil companies on profits and operations.[79] The character of the forms and of questions asked witnesses when hearings began confirmed the suspicion that La Follette was on the scent of monopoly.[80] The feeling grew in the industry that La Follette's investigation was "biased" and "political," as the hearings made headlines for the rest of the year, and when his report was submitted to the Senate, it left no doubt of this.[81]

La Follette threw the book at the "Standard Oil monopoly," arraigning Standard Oil as a price dictator, predicting $1 a gallon gasoline, and demanding regulation. The *New York World* questioned La Follette's findings in an editorial titled Still a Standard Oil Monopoly?[82] Said the *New York Globe*:[83] "Shot through the Senate report on the oil industry is the almost expressed belief that mere size in business is an evil." *The New York Times* said editorially:[84] "It will doubtless be a difficult process to attempt to overtake the La Follette report, which has got so good a start in the newspapers which have freely published it, and to correct its errors one by one. But it is a duty which the Standard Oil people owe to themselves and to the general public." President Teagle denied the Standard Oil monopoly charges and ridiculed La Follette's dollar gasoline prediction.[81] "As to any unjustifiable increase in the price of gasoline," he said, "I will say that the availability of industrial alcohol, benzol, and other substitute motor fuels at moderate prices fixes a limit beyond which the price of gasoline cannot rise."

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[76] *New York American*, Nov. 7, 1921.

[77] *New York World*, Nov. 29, 1922.

[78] *Nation*, Feb. 14, 1923.

[79] *Natl. Petroleum News*, July 21, 1922.

[80] *Wall Street J.*, Aug. 8, 1922.

[81] *The New York Times*, Mar. 5, 1923.

[82] *New York World*, Mar. 6, 1923.

[83] *New York Globe*, Mar. 6, 1923.

[84] *The New York Times*, Mar. 6, 1923.

La Follette repeated his charges, and let it be "no secret" that one of his first acts when Congress reconvened in December would be to insist on legislation to curb the "Standard Oil menace."[85] When the United States Coal Commission proposed public operation of coal and "other fuel" resources, it seemed certain that the La Follette group would "seek to extend its recommendations for Federal control to cover oil."[86]

The ink was scarcely dry on Senator La Follette's report predicting dollar gasoline before prices tumbled. Oklahoma-Kansas crude oil dropped from $2 in February to $1 a barrel in November, 1923. Motorists who were paying around 21½ cents on an average in March were being charged only 13.8 cents in December. United States crude-oil production for the year totaled 732 million barrels, double the great wartime peak of 1918—double in five years! Successive discoveries of the new fields in the Los Angeles basin of California—Elk Hills, Huntington Beach, Santa Fe Springs—had counteracted the decline of Mexico's Golden Lane. And Hewitt, Tonkawa and Burbank in Oklahoma, Smackover in Arkansas, Big Lake in Texas—a whole flock of Cushings—flooded the American market with oil.

Instead of cries of shortage, already voices in the industry were being raised warning of overproduction—warning that overproduction waste would bring the Federal and state governments down on the industry's head. E. W. Marland, president of the Marland Oil Company, told the oilmen assembled at the International Petroleum Exposition and Congress that overproduction in new fields was a natural result "of the present system of unregulated competition between operators" and that one approach to a solution was "intelligent and uniform proration of purchases from flowing wells."[87] To this end he suggested "legislation permitting purchasers and carriers to enter into agreements regarding proration during periods of overproduction."

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[85] *The New York Times*, Mar. 14, 1923.

[86] *Calif. Oil World*, July 12, 1923.

The *Oil and Gas Journal* summarized the industry's chief problems as evidenced by statements of leading oilmen and resolutions passed at various oil associations as including the "necessity of controlling crude-oil production so as to keep it as close to current requirements as possible."[88]

A far cry from the shortage scare that had been grabbing the headlines since the end of the war! Suddenly the industry faced possible regulation, not because of "monopoly prices," but because of surplus conditions that wrecked prices! The problem now was one of overproduction, not underproduction. Our era of oversupply had begun. The problem was one of conservation of a valuable, irreplaceable natural resource and of reducing the physical and economic waste entailed in overproduction.

By 1924 all talk of oil shortage, all immediate fears had ended. According to the apostles of despair of the early 1920's, in the foreign area almost alone could failing United States reserves expect necessary succor—in this area, and in that of substitute and synthetic fuels. Actually, many American companies which had gone abroad for oil—particularly some which had had disastrous experiences in Mexico—forsook all foreign operations. They were getting all the oil they needed—and more—at home.[57]

The year 1923 also marked the climax of the prolonged tension over oil supplies among the former Allies, Britain, France, and the United States, as the John Bull scare died down for lack of ammunition because of the opening of large new oil fields in the United States. The Netherlands government relaxed its policy of exclusion and allotted to the Standard Oil Company (New Jersey) concessions in Sumatra and other Dutch East Indies islands. Eventually President Coolidge rescinded the exclusion of the Roxana Petroleum Company from United States held Indian lands. Out State Department's intervention in the Middle East bore fruit, but not until 1928, when an American company, the Near East Development Corporation, gained a 23.75 per cent interest in the Iraq Petroleum Company, successor to

[87] *New York Tribune*, Oct. 11, 1923.

[88] *Oil Gas J.*, Oct. 11, 1923.

the Turkish Petroleum Company. The State Department invited wide participation in Iraq among American oil companies, and the original shareholders numbered five—Atlantic Refining Company, Pan American Petroleum & Transport Company, Gulf Oil Corporation, Standard Oil Company of New York, and Standard Oil Company (New Jersey). The Atlantic, Gulf, and Pan American companies subsequently withdrew.

The near shortage, as one might call it, was corrected not by signal increases in foreign oil production. It was solved not by institution of oil-shale mining and processing or by the building of plants to refine grain into alcohol for motor fuel. Shale oil and alcohol were the synthetics and substitutes most talked of during the period. Except for a small production of benzol from coke ovens, no ersatz motor fuel reached the market. But a gullible public bought into oil-shale exploitation with a vengeance. There was a lamentable record of fly-by-night oil-shale companies. Of over 250 companies organized in 1922, only 19 erected experimental plants,[89] and Dr. Victor Alderson, of the Colorado Bureau of Mines, a pioneer in the field, called it the "shale game" in 1923.[90]

Nor had it been necessary for the government to create great aboveground storage of petroleum to ensure supplies for the Navy and merchant marine, although for a time a great expansion of tankage went on at Pearl Harbor and in San Francisco and Seattle harbors, filled with Elk Hills naval reserve oil. But Teapot Dome proved disappointing, and both leases were canceled after protacted legal action begun by President Coolidge on Jan. 29, 1924.

It was unnecessary for the government to acquire lands in foreign oil fields strictly for use of governmental departments, as had been proposed. It was found unnecessary, further, for the government to stock-pile oil either in the United States or abroad. Nor was it necessary to form the United States Oil Corporation or to embargo oil exports. And La Follette's prediction of dollar gasoline—constituting the peak disaster warning of the period—never came even close to being right.

The John Bull shortage scare was spiked by the American oilman's drill at home and abroad, drowned in a flood of oil.

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[89] *N. Y. J. Commerce*, Apr. 28, 1921.

[90] *Mining Congr. J.*, January, 1923.

5. The Ickes' Petroleum Reserves Corporation Scare—1943 to 1944

We Americans have a notoriously short memory. The odds are against many of us remembering the oil-shortage scare that broke loose in 1943–1944, when the Second World War was still going on—the Ickes' Arabian pipe-line scare. In November, 1943, Petroleum War Administrator Harold L. Ickes, Secretary of the Interior, permitted it to become known that a Federal company known as the Petroleum Reserves Corporation (PRC) contemplated the building of a pipe line from the American-discovered oil fields in Saudi Arabia to the Mediterranean coast.

A corporate creature of the Reconstruction Finance Corporation, the PRC's birthday was June 30, 1943, just a day before the expiration of authority for granting such a type of company under the Reconstruction Finance Corporation. Because of the deliberate secrecy surrounding its birth, charter, and early activities (its vast charter powers included not only the building of pipe lines and refineries in foreign countries but other activities as well), PRC provoked widespread discussion and speculation. The evident intent was that our government go directly into the foreign oil business.

Ickes, who under the charter was president of PRC, blew the lid off it in November, 1943, when he told the oil people:[91] "The United States is one of the few major countries which has not participated in foreign oil activities through governmental financing or direction.... To the extent that private capital and private initiative are unable to establish and maintain a national position in this field, government assistance and participation may be necessary. The PRC is available for these purposes whenever and wherever necessary."

Most of the oil people saw the PRC as a danger signal—the use of a war emergency corporation to create international commitments in the field of foreign policy and to cover up a government postwar project in the realm of private enterprise.[92]

Ickes' next statement on the PRC appeared in an article in the *American Magazine*, January, 1944. Significantly it was titled

[91] *Proc. Ann. Meeting. Am. Petroleum Inst.*, Nov. 11, 1943.

[92] "U.S. Foreign Oil Policy and Petroleum Reserves Corporation," an analysis of the effect of the proposed Saudi-Arabian pipe line, Petroleum Industry War Council, March, 1944.

"We're Running Out of Oil." The Petroleum Administrator's campaign to put across the Arabian pipe line was themed on an oil shortage to come—an oil-shortage scare.

Naturally, the American public could be expected to place credence in this line, for beginning in 1941, as North and South American oil increasingly became the chief reliance of the Allied Powers, a scare had been built up step by step in the public consciousness. It was based on facts of wartime available oil supply and demand and transportation. These steps should be briefly outlined.

Early in 1941—a full eight months before we entered the war—German submarines ravaged Atlantic shipping, sinking 182 British tankers, January through April. To aid Britain, President Roosevelt turned 50 American tankers from their regular runs and had them placed in "shuttle service," moving oil for Britain from the Gulf coast to North Atlantic ports, where it was pumped into British tankers for the rest of the voyage to foreign destinations.[93] The immediate effect was insufficient transportation to move enough oil to the east coast to meet the demand there—an "oil shortage."

Motor-riding and oil-burning American families along the Eastern seaboard had it dinned into them through ads and over the radio throughout the summer and fall of 1941 that they must conserve oil. The oil industry spent $250,000 in advertising alone, asking motorists to buy less. It was the first of many instances during the prewar and war period where industry voluntarily advocated the cutting of nonessential civilian consumption of its own products. Ickes and his Office of Petroleum Coordinator (OPC) [which after Pearl Harbor became the Petroleum Administration for War (PAW)] lent their voices to the campaign.

In certain cases, motorists could buy only a limited quantity of gasoline at service stations because of supply allocations. Nevertheless, few people reduced their driving, and not a few were critical of the tanker deal that interfered with their civilian activities. On behalf of their constituents, politicians in Washington and locally cast doubt on the need to conserve. They called it a "phony scare." It was as with the gasless Sunday scare during the First World War. Ickes, being particularly vocal in calling on oil users to desist, bore the brunt of the attack. A war history of PAW recalls:[94] "The cries of phony shortage from uninformed groups effectively dampened the patriotic response encouraged by the oil-company advertising and the pleas of the government. To many, Ickes was just shouting wolf again."

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[93] "A History of the Petroleum Administration for War, 1941–1945," U.S. Government Printing Office, Washington, D.C., p. 85.

The OPC, lacking power to ration, on Aug. 18 recommended that east-coast companies reduce deliveries to service stations. The public's resistance continued. A Senate committee, headed by Senator Mahoney of Massachusetts, investigated. Publicity accompanying the Mahoney committee hearings did not help the public's understanding. Nor did the committee's report in September, concluding as follows:[95] "Paradoxical as it sounds, the shortage, as we see it, is a shortage of surplus, not a shortage of products or lack of transportation." One might add parenthetically, paradoxical is right.

"The Mahoney committee succeeded only in contributing misinformation and confusion to an admittedly complicated situation, with the result that the government's efforts to prepare for war—that was only a few months distant—were seriously obstructed," the PAW history says.[96]

Nevertheless, the War Production Board backed up the OPC with an order, effective Oct. 1, restricting gasoline deliveries to all distribution levels according to a formula based upon previous sales.

Meantime, the oil industry, acting in cooperation with the OPC, worked out a tremendous rail movement of oil and speeded construction on the Plantation and South Eastern pipe lines feeding into the Eastern states (while Ickes began his successful advocacy of a superpipe line from Texas to the north Atlantic, later to come through as two lines, the "Big Inch" and "Little Big Inch."). So effective were the measures taken that relief was assured even as in October and November the British returned most of the borrowed tankers, apparently putting an end to the trouble. By Nov. 30, 1941, all restrictions on civilian oil consumption were suspended, encouraging the skeptical to continue to dub it the phony shortage.

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[94] "A History of the Petroleum Administration for War, 1941–1945,' pp. 84, 119.

[95] Preliminary Report Pursuant to S.R. 156 of the Special Committee to Investigate Gasoline and Fuel Oil Shortages, Senate 77th Cong., 1st Sess., *Rept.* 676, Sept. 11, 1941.

[96] "A History of the Petroleum Administration for War, 1941–1945," footnote 5, p. 119.

But this, the first step in the education of the public to "oil shortages" and consumer curtailment in the Second World War period, was simply a foretaste of what was to come after Pearl Harbor.

Diversion of oil products to military use after we entered the war in December, 1941, complicated by severe tanker losses in the Battle of the Atlantic, created a second deterioration of the civilian oil-supply situation on the east coast. But the new "oil shortage" again had a phony ring to many. The first rationing covered only the east coast. When the government slapped it on gasoline (May 15, 1942) and introduced the coupon system (July 22, 1942), the outcry in the East was deafening.

The nation as a whole was on a voluntary motor-driving-slowdown, conservation basis *to save rubber* (tires). Everyone pitched into the national scrap-rubber drive, which, though successful, did not solve the rubber-shortage problem. The Baruch committee issued its famous report on Sept. 10, 1942, advocating the building of synthetic-rubber plants in the United States and recommending *nation-wide gasoline rationing to save rubber.* When the latter was formally announced in November, 100 congressmen, reflecting the anguished protests from the West, staged a demonstration.[97]

On the east coast (and in the Pacific Northwest) restrictions were imposed on fuel-oil deliveries and on installations of oil-burning equipment. On Mar. 14, 1943, the WPB prohibited new installations of oil-burning equipment and encouraged the conversion of heating equipment from oil to coal.

Up to this time, it was a rubber shortage, not an oil shortage, that was impressed on the public asked to curtail motor driving. This was not conducive to clear understanding. (No one can say that at any time an "oil shortage" has been uncomplicated.) Recommended several times by PAW and ordered several times by the OPA, pleasure-driving bans were misunderstood and much abused. These were confined to the east coast, where "oil shortages" were most desperate. Black markets flourished. Many

[97] "A History of the Petroleum Administration for War, 1941–1945," p. 121.

patriotic people reduced their driving and even laid up or sold their cars—but gasoline could be had if you'd pay the price.

The need to conserve oil in this area was continually publicized by PAW and other government agencies, by oil companies and advertisers in other industries. Oil shortage (in the East) became a by-word, while the public's understanding of the nature and the causes of the shortage continued confused. Why an oil shortage on the east coast and not elsewhere?

With psychological as well as practical objectives in view, PAW instituted a "sharing the shortage" policy, which was in process of evolution throughout the war.[98] In a nutshell, it consisted in a pooling of supply and the drawing on the available supplies wherever they were to meet conditions of emergency elsewhere. This was an internal oil-distribution device of share and share alike. It tended to "equalize" shortage conditions, thus bringing people in areas other than the east coast to a growing perception that oil supply was insufficient for *both* essential war need and unrestricted nonessential use. It also served as an effective device to implant in the public consciousness an actual, possible, or impending oil shortage.

The tremendous oil needs of the United States Army and Navy, of the United Nations, in waging war and in developing war industries, became increasingly apparent to all as our armed services expanded and the war material to support them came off the production lines. After the landing of our forces in Africa in the winter of 1942 and the opening of our Japanese campaign in 1943, this realization took form in military discussions of the vital role oil played for or against victory in battle. Hitler helped fan a fear of oil shortage in war by advancing within a hill or two of Russia's great Baku oil fields in one arm of his pincers move to close in on both Russian and Middle East oil.

The publicity attending the promulgation and building of the Big Inch pipe line from Texas to the east coast—the first leg of the Big Inch from Longview, Tex., to Norris City, Ill., was completed early in 1943—brought home the oil needs of the military. The Big Inch and Little Big Inch, representing an investment of 138 million dollars, served to dramatize a close shave between making good or falling down on the job of meeting war requirements for petroleum. Indeed, it is doubtless true that had the Big Inch not been built, vital battles would not have been won.[99]

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[98] "A History of the Petroleum Administration for War, 1941–1945," p. 129.

Finally, in October, 1943, traveling members of a subcommittee of the Special Senate (Truman) Committee Investigating the National Defense Program, returned from a visit to the war theaters, revived the ghost of the John Bull scare, and precipitated a public debate on foreign oil plenty versus American oil scarcity in addresses delivered on the floor of the Senate.[100]

"Up to now, we have been depleting our petroleum stocks at a ruinous rate, supplying not only our own forces but those of our allies," Senator Richard B. Russell of Georgia said. "It is now time to utilize the petroleum deposits of other parts of the world. Otherwise, the end of the war will find our own deposits practically exhausted." "It is a matter of common knowledge that we are exhausting our own domestic resources and that all of our people, particularly those on the Eastern seaboard, are experiencing a shortage of petroleum," Senator Henry Cabot Lodge, Jr., of Massachusetts said. And Senator James M. Mead of New York declared: "With 25 per cent of the oil reserves of the world, [the United States] has been furnishing over 60 per cent of the United Nations' demands."

"While Britain has oil reserves at least equal to the United States, the British reserves at the present rate of consumption will last 100 years," Senator Owen Brewster of Maine, the fourth member of the subcommittee, said. "Only 8 per cent of the oil consumption of the United States is at present coming from British sources, while 80 per cent is coming from United States reserves. . . .Before another generation comes on the stage, America will be a mendicant for petroleum at the council tables of the world. This generation must bear then the responsibility for dissipating this most precious heritage. Equitable distribution of available supplies to meet the military needs of the United Nations is all that is desired. Is this treason?"

Senator Brewster's cry "Is this treason?" was provoked by criticism of the traveling Senators to the effect that they were imputing blame on a war ally, Britain, for not making sufficiently available to the United Nations oil from sources under her control. The Senators, in a word, had poked the old hornet's nest, United States scarcity versus British plenty, by now a familiar interpretative manifestation of an oil-shortage scare.

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[99] Oil for Victory, editors of *Look*, 1946, p. 114.

[100] Report of Subcommittee Concerning Investigations Overseas of Special Committee Investigating the National Defense Program (Truman Committee), Feb. 16, 1944.

It was at this propitious time that Ickes sprang the PRC. Step by step enough had happened to crystallize public consciousness of fear of an actual, possible, or impending oil shortage.

Additional details of the plans for the PRC were announced.[101] An agreement in principle had been entered into between the United States government and the Arabian American Oil Company and the Gulf Exploration Company to assist them in the development of their interests in the Persian Gulf area. The PRC would finance a pipe line and a reserve of 1 billion barrels of oil for the naval and military forces of the United States. This would be on a liquidating basis that would guarantee to the government complete repayment of its investments and costs. Supporters argued the need on the basis of an adequate supply of petroleum for the United States armed services "in the post-war world."

The preamble of the outline of the principles of proposed agreement emphasized security and implied future oil shortage, stating: "Upon the recommendation of the War Department, Navy Department, Joint Chiefs of Staff, and the Army and Navy Petroleum Board and with the approval of the Department of State, the afore-mentioned parties, in appreciation of the critical importance of reserves of petroleum in war and in peace and of the necessity of assuring to the military forces of the nation and to the people of the United States adequate petroleum supplies, have agreed upon the principles of the understanding. . . ."

The Truman subcommittee in its report of Feb. 16, 1944, referred to the "current [oil] emergency" and hinted at even further steps being taken (beyond the PRC) to meet it. "The critical importance of petroleum in the world economy," it said, "is emphasized in the current emergency. There have been suggestions that international arrangements may be considered assuring the access of all nations to petroleum reserves for their peacetime economy upon an equitable basis. [Rumors of an Anglo-American oil agreement soon began to be heard.] Such a possibility accentuates the imperative necessity of an early determination of a national policy on petroleum by the Congress." The report also suggested that the United Nations, "particularly Great Britain," be requested "to recompense the United States" for what was called "excessive depletion of our domestic resources in providing for the war."

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[101] President of Petroleum Reserves Corporation Statement of Feb. 6, 1944, *Congressional Record*, Feb. 9, 1944, pp. 1468–1469.

As stated, most of the oil people assailed the PRC project.[92] It would put the government right in the oil business. It violated the Atlantic Charter. It was a commitment on foreign policy in an explosive area of the world. An Arabian pipe line in itself would not create one more barrel of oil reserves. The PRC should be dissolved.

It is not within the scope of this case history to air the Petroleum Reserves Corporation battle of 1944 except as it contributed to and exploited the oil-shortage scare psychosis. President Roosevelt, at a press conference at which he inferentially defended the project, expressed the opinion that we needed foreign oil for the existing war, if it kept on going, and for the future.[102] Again, as the Senate set up a committee to investigate the project, he asserted that criticism of the Arabian pipe line involved the question of supplies—a question largely of facts—and said he was worried about the nation's petroleum supply in the future—not in the next 5 or 10 years, but in the next 50.[103]

The urgency felt by the United States military chiefs respecting oil requirements for the war also was eloquently demonstrated around this time by their advocacy of PRC and the Arabian pipe line and in other ways. The Army had secretly embarked on the (Canadian) Canol project. This was smoked out by Petroleum Administrator Ickes.[104] "After all, there is no denying the fact that the moneys, materials, and labor for the construction of the refinery at White Horse and the pipe line from Fort Norman have all been provided by the United States," Mr. Ickes told the Truman committee in reviewing the Canol project. "I am told that this exploration has resulted in the discovery of substantial reserves. In view of my own concern over the prospective shortages of oil in the continental United States, I am delighted that this is so."

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[102] *New York Sun*, Feb. 11, 1944.

[103] *New York Herald Tribune*, Mar. 4, 1944.

[104] Statement of Harold L. Ickes before U.S. Senate Special Committee to Investigate the National Defense Program (Truman Committee), Nov. 22, 1943.

The Navy for its part, urged the opening of its 35,000-sq-mile "untouched reserve" at Point Barrow, Alaska. (President Harding had created this as Naval Oil Reserve No. 4.) Representatative Norris Poulson of California told the House that "failure to develop the Point Barrow reserve cost the taxpayers of this country 130 million dollars, which was paid for the Canol project.[105] Legislation was passed to step up production in the Elk Hills Naval Ore Reserve No. 1 in California.[106]

It was in this atmosphere of urgency and fear about oil that Congress took up and passed the O'Mahoney (Senator Joseph C. O'Mahoney of Wyoming) bill authorizing a five-year synthetic liquid-fuels research program.[107] An appropriation of 30 million dollars was made for construction by the Bureau of Mines of demonstration plants to produce synthetic liquid fuels from coal, oil shale, and other minerals.

For several months the PRC controversy shared the headlines with the military news. The proposed Congressional investigation of PRC broadened into a far-reaching investigation of all aspects of foreign oil policies. The *Oil and Gas Journal* commented:[105] "It is apparent that millions of consumers are convinced that a permanent shortage exists in this country, and it is on the fears that arise from this belief that sponsors of the governmental participation in oil operations here and abroad are largely backing their case. The average consumer still does not realize that petroleum rationing has been brought about entirely by the war's restrictions in operation. There is danger that he will support any program which he is led to believe will assure adequate petroleum supplies in the future, regardless of economic and political complications to him and to future generations. Never were there greater need and opportunity for sound legislative leadership than now."[105]

A body blow was dealt Ickes' PRC project by the Petroleum Industry War Council, which condemned it. Its National Oil Policy Committee, having been constituted at Mr. Ickes' request to obtain the industry's viewpoint, submitted a draft of a pro-

[105] *Oil Gas J.*, Mar. 2, 1944.
[106] *The New York Times*, June 18, 1944.
[107] *Nat. Petroleum News*, Mar. 29, 1944.

posed national oil policy which deplored the current oil-shortage scare.[108] The oilmen comprising this committee asked the government to proceed deliberately and only after mature study in formulating an oil policy. They urged "that no definite action be taken by any arm of the government committing the people to long-range future entanglements in foreign countries without approval of Congress."

The committee's report, dated Feb. 28, 1944, took issue with some other drastic measures to "forestall or meet an oil shortage" which were being variously proposed at the time. Stock piling of crude oil and its products (such as proposed in Arabia and in the United States) was one. Stock piling in sufficient volume to be of importance for national security would not in fact promote true national security, the committee declared. Importing oil and pumping it into depleted or partially depleted oil or gas fields in the United States was impracticable. Locking up proven reserves by suppressing existing production or by acquiring proven oil fields through purchase or condemnation would be "harmful to the hope of a continued, vigorous domestic industry."

It concluded: "(1) The public interest in oil can best be served by a vigorous competitive industry, guided by private initiative. (2) Our oil future cannot be charted in advance; our best procedure is to maintain a vigorous, dynamic oil industry competent to meet the problems as they arise and able to create new approaches through dynamic action. (3) The domestic oil industry needs no further Federal administrative machinery. (4) The operation of United States nationals in foreign fields needs diplomatic support and machinery for international consultation. (5) The government of the United States should develop deliberately and only after mature study, an oil policy, both domestic and foreign, based upon experience, knowledge, and insight."

So vigorously was the campaign conducted against a government-financed Arabian pipe line that the Senate investigating committee finally asked and received assurance from Ickes that no further steps would be taken by the PRC pending the inquiry. Meanwhile, Ickes had become the father of a new idea—an Anglo-American oil agreement. By early April, 1944, the first conference on this with British representatives was in session in Washington, and the PRC definitely took a back seat.

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[108] Text of Preliminary Report, A National Oil Policy for the United States, Feb. 28, 1944, "A History of the Petroleum Administration for War, 1941–1945," p. 395.

However, the Army and Navy fought hard to save the Arabian project to build a pipe line and establish reserves in Arabia, citing alarm over United States oil along with military considerations.[109] Reminiscent of Josephus Daniels, another Secretary of the Navy Frank Knox, found the United States "selling its oil as if our supply is inexhaustible" whereas "it isn't." He did not believe the American people "are going to let a lot of selfish oil companies" divert the nation from the formulation of a "foreign oil policy."[110] The Joint Chiefs of Staff had "formally approved" the Arabian project primarily as a military necessity and secondarily because the United States was depleting its oil resources "very rapidly" and at a "dangerous rate." Unless we began to develop new sources for war needs, we might find ourselves a "have-not" nation in petroleum after the war. Secretary Knox's official admission that the government had sought to purchase outright the entire rights of American oil companies in Saudi Arabia created a sensation.[111]

Ickes tried to reassure the oil industry as to government intentions in Arabia. Representative Jerry Voorhis of California, advocating government construction of common-carrier pipe lines "to discourage monopolistic control of the country's petroleum industry," blamed policies of big oil companies for the "shortage."[112] "It is apparent that although Mr. Ickes feels called upon to assure the private oil industry that the government will not assert the public interest to any great extent in their private domain, the major oil companies have no hesitation about stressing again and again the importance of their work in determining a policy for the government," Mr. Voorhis told the House. "I fear that the major oil companies are getting into the government in competition with the American people."

It will be noted that throughout this period the question of oil shortage was in controversy. Oil-industry authorities insisted that "too much anxiety over the adequacy of the nation's oil resources is not justified," that "exploratory drilling is handicapped by wartime shortages of equipment and man power and by a ceiling price for oil which frequently does not cover the costs of replacing the reserves sold," and that "once conditions are again favorable, we can look to additional discoveries of oil not only in this country but throughout the world."[113]

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[109] *New York Herald Tribune*, Mar. 21, 1944.

[110] *The New York Times*, Mar. 22, 1944.

[111] *Wall Street J.*, Apr. 14, 1944.

[112] *New York World Telegram*, May 8, 1944.

It remained for Senator E. H. Moore of Oklahoma, who first attacked the government's PRC Arabian pipe-line project as a "bad, bad deal"—and who was Ickes' archenemy in opposition to it throughout—to be the first to pronounce its imminent demise. Calling it a "dead duck," he said:[114] "There probably will be permitted a cooling-off period purely as a face-saving gesture before any announcement is made that the Arabian deal got too hot."

Meantime the American oil companies holding concessions in Saudi Arabia, Bahrein Island, and Kuwait—the Standard Oil Company of California, the Texas Company, and the Gulf Oil Corporation—proceeded with oil development and construction of refineries and other facilities in the area despite the continuing controversy over proposals to connect these facilities with the Mediterranean by a government-financed pipe line. (After the war, the Arabian American Oil Company went ahead with the building of the Arabian pipe line on its own.)

When on Aug. 8, 1944, the Anglo-American Oil Agreement, "to assure the orderly development of petroleum resources for international trade and to provide the basis for a multilateral world-wide oil accord in the postwar era," was signed by representatives of the United States and the government of the United Kingdom and Northern Ireland, the Petroleum Reserves Corporation controversy stepped aside for what developed into a new controversy—that over this agreement, which never has become effective, since it still awaits United States Senate ratification. As predicted, the PRC proved to be a "dead duck."

This may be taken as the approximate time that the oil-shortage scare of the Second World War, having ridden high, wide, and handsome, was sent to cover by continuing success of the oil industry in meeting essential oil requirements. Although the war demand for products mounted, the oil industry in a remarkable job of teamwork with PAW, found the necessary oil and developed adequate transportation and refinery capacity. Although, to conserve steel and other materials, the industry was held to well-spacing controls based on efficient operating principles and other restrictions which resulted in fewer wells being drilled, United States production increased from 3,842,000 bbl daily in 1941 to 4,695,000 bbl daily in 1945.[115] Also this was accomplished despite the OPA's position, counter to the PAW and the oil industry, in refusing to increase crude-oil prices so that wildcat drilling might be stimulated.

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[113] *Oil Weekly*, May 1, 1944.

[114] *Wall Street J.*, May 16, 1944.

The oil-shortage scare subsided in the face of such concrete achievements by the government-industry oil team as the following: increased refinery runs in the United States of more than 1.4 million barrels daily; a billion-dollar plant-construction program for 100-octane aviation gasoline; an improvised overland transportation system involving building, relaying, or reversing 17,000 miles of pipe line, rearranging barge movements on inland waterways, and mobilizing 75,000 tank cars to serve the east coast; an increased natural-gas production from 2,812,638 million cubic feet in 1941 to 3,918,868 million cubic feet in 1945; supplying the essential civilian requirements for petroleum products while meeting every demand of the armed forces in full and on time.

The Army's Canol project added no oil worth mentioning and no large proved reserves, as promised. Elk Hills Naval Reserve No. 1 added but little oil while the war was on. Needed oil was not "pulled out of a hat" by special projects. It came from the reserves built up over the interwar years by the oil industry—more than three-quarters of proven oil reserves in the United States, it was estimated, having been discovered and developed before Pearl Harbor—and by the addition to domestic reserves made by the industry while the war was going on. It came from supplementary foreign oil supplies—chiefly from Venezuela and the Middle East—the bulk of these reserves also having been discovered before we entered the war.

6. The Cold War Scare—1946 to 1947

After the Second World War, in which petroleum products played such a vital part on the battle and home fronts, it was an oil-conscious world—even more so than after the First World War. Particularly was this true in the United States, the greatest oil-producing and -consuming nation and the supplier of the bulk of the United Nations' war demand.

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[115] "A History of the Petroleum Administration for War, 1941–1945," p. 185.

Moreover, postwar events were not conducive to letting the military importance of oil cool off like the guns, so to speak. Soviet Russia occupied or took over control of country after country in eastern Europe—among them Rumania, Poland, Hungary, part of Austria, Yugoslavia, and finally Czechoslovakia, all oil-producing—perpetrating a gigantic oil grab, confiscating oil products, facilities, and properties. She violated a treaty and prolonged the stay of her troops in Iran, then the largest oil-producing country of the Middle East, precipitating the first United Nations Organization crisis. In a word, she launched the Cold War. A concommitant of it was an oil-shortage scare in the United States—the Cold War oil scare.

The first evidences of its approach came in August, 1946, when top oil-policy planners of our State Department went on the air with predictions of failure of the United States oil supply and with a plea for a "world-wide oil authority." Their debate created a sensation.[116] It had the old familiar ring of oil-shortage scare.[117]

Although oilmen of every interest and department had been heard at exhaustive hearings, held in 1945 in Washington by the Senate (O'Mahoney) Special Committee Investigating Petroleum Resources, and our oil position had been aired in the press for months in that connection, no particular warning had been sounded of impending shortage. Hence the thesis of the debaters came as a surprise to the public. They were arguing in favor of the stalemated Anglo-American Oil Agreement and were supported on the broadcast by members of the Army-Navy Petroleum Board representing the Joint Chiefs of Staff of all our military services. (The Anglo-American Oil Agreement was—and still is—locked up in the Senate Foreign Relations Committee.)

"I'm no prophet and I don't propose to get into a statistical battle," John A. Loftus, chief of the Department's Petroleum Division, one of the debaters, said. "But I think it is safe to say that by 20 years from now, we shall have to import close to half the oil we consume—unless some large new oil fields are discovered, and we can't count on that."

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[116] Broadcast, Our Foreign Policy, under State Department auspices, Aug. 17, 1946; *Natl. Petroleum News*, Aug. 21, 1946.

[117] *The New York Times*, Aug. 18, 1946.

Charles B. Rayner, the State Department's petroleum adviser, his partner in the debate, declared that "some sort of world-wide oil committee or authority under the United Nations might be the answer." "The governments of the United States and Great Britain, when they signed their agreement [the Anglo-American Oil Agreement]," he said, "undertook to convene a world oil conference at an early date to establish such a world-wide organization. The sooner this can be done, the better the chances are for stability and prosperity in the oil industry and international oil relations in general."

Obviously designed for public attention, the broadcast got it. The radio debate on "world oil" developed into a political and public debate on a possible United States shortage.

"These assertions that were broadcast so frankly contain much of great significance," said the *National Petroleum News*.[118] They came at a time when Russia was looking down the broad Iranian and Iraqian oil country, undoubtedly with covetous eyes; when Secretary of State James F. Byrnes was vigorously contesting Soviet aggression and expansionism. The speakers called the control by American companies of 42 per cent of all Middle East oil "extremely important."

"Our military minds today were mightily impressed with the importance of petroleum in war, more by far than when they went into World War II," the editorial continued. "Hence the decision that prompted the broadcast may well be said to be a military one which suggests that future decisions as to our oil supplies will also be first decided from the military standpoint . . . . By the same token Great Britain's large oil interests will undoubtedly also be controlled largely by military decisions. What this leads up to is that the American oil industry, as well as the British, will be asked to consider subordinating somewhat their free-enterprise ideas for military expediency . . . ."

The paper, however, disagreed as to the shortage scare and warned against Government control of the industry under the guise of security.

"[The *National Petroleum News*] does not believe that any disastrous shortage of oil supplies will be on us tomorrow," the editorial concluded. "But it is most certain that the industry is now confronted with a most important and complicated military supply problem and organization for future military operations. And it also is most certain that the industry has before it the political problems that come naturally from any attempt to tackle these military problems. We easily can go down the road of more and more government control, or if the problems are approached broad-mindedly, the industry may be able to marshal its resources for our military needs and civilian requirements, meet the difficulties of foreign oil holdings, and still be a free and independent American industry."

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[118] *Natl. Petroleum News*, Aug. 21, 1946.

When later in 1946 a broad program of participation by American companies in transportation and marketing of Arabian, Iraqian, and Iranian oil was announced, our State Department officials hailed it as "welcome news" in so far as it would relieve the drain on "dwindling oil resources of the United States and South America."[119] Meantime, the Arabian American Oil Company was proceeding with the building of a pipe line to the Mediterranean up to its ability to obtain pipe.

The State Department's broadcast was perfectly timed with Secretary of the Interior Julius A. Krug's "first statement of the Truman Administration's petroleum policy," which also sounded a shortage alarm.[120] "A summary of expert opinion as to the quantity of oil we may hope to find through future exploration," he said, "indicates that we have about reached the halfway mark in oil discovery in the United States. Finding the second half will take much longer, be much more costly."

Indeed, Krug revived the "United States scarcity, foreign plenty" approach, so conspicuous during the John Bull scare following the First World War. "Ultimate oil resources of the United States, according to the experts, will amount to about one-sixth of the total oil resources of the world, and we are producing and using about two-thirds of the world's oil," he declared. "This means that oil will be scarce in the United States long before there is a comparable scarcity in other important producing areas. I believe the industry must soon accommodate its thinking to the need for substantial petroleum imports which can increase our security without being any threat whatever to a healthy domestic industry."

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[119] *The New York Times*, Dec. 27, 1946.

[120] Address before Interstate Oil Compact Commission, *Oil Gas J.*, Aug. 17. 1946.

Oil-industry authorities although predicting a period of great expansion of oil consumption ahead sounded no particular shortage warning. However, the world fuel (coal) shortage, and, because of it, a growing pull on oil for fuel, was fully recognized. And a significant change in American oil was noted: United States oversupply days were passing.[121] As expressed by one authority: "The outlook now is that, while reserving its healthy competitive structure, the [oil] industry will grow out of its tradition of excess production. Indications are that this tradition will give way to a situation in which demand will tend to outbalance domestic supply. This, of course, will mean importation of foreign oil but will also tend to strengthen the position of the domestic producer. He will have his oil close at hand to the world's biggest market, and for this reason his oil will be more valuable. On a global basis, demand likewise is moving closer to supply, and the world-wide fuel shortages are emphasizing this fact. The trend is toward a wider use of petroleum products for fuel purposes, thus creating more markets to absorb available oil."

Former Deputy Petroleum Administrator Ralph K. Davies, before resigning from the Department of the Interior to return to his station as a private oilman, called for discovery of new oil supplies at a much higher tempo than had prevailed in recent years.[122] Although he believed the "discovery rate" could be increased sufficiently to meet anticipated needs, he urged aggressive exploration for new sources of oil in domestic regions, as well as increased oil imports.

When OPA price ceilings and controls finally were removed late in 1946, a series of price increases for crude oil began. Exploration for new production was stimulated. As these rises were reflected in gasoline and fuel oil, public attention to the closely balanced supply and demand situation became assured and personal. At the end of the year prices were the highest in 15 years.

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[121] H. D. Collier, Chairman of the Board, Standard Oil Company of California, *Natl. Petroleum News*, Oct. 30, 1946.

[122] Testimony before House Committee on Interstate and Foreign Commerce, *The New Tork Times*, Dec. 12, 1946.

While the oil industry had no difficulty in meeting the demand during the mild 1946–1947 winter, price advances served to support statements of possible shortage. But the emphasis remained on "oil and security."

In January, 1947, the House (Lea) Oil Subcommittee touched a note of security alarm.[123] It appealed for mutual hemispheric oil development by all Western Hemisphere countries. Advocating a nine-point security program of exploration and development, research and conservation, the committee said: "The kind of oil reserves we need for security are those which can be promptly supplied with the least practical need for more critical materials, more capital, and more man power, when these will be scarce and urgently needed for other purposes."

The report of the Special Senate (O'Mahoney) Committee Investigating Petroleum Resources sounded the security note, emphasizing the urgency of having a national oil policy "which will make certain that we shall not become dependent upon any other country for our supply of liquid fuel."[124]

"In this troubled world, which has not yet learned how to avoid war," the committee warned, "the oil policy of this nation while at peace must nevertheless be governed by the inexorable demands of self-preservation." To this end it recommended (1) all-out encouragement by private industry, "unhampered by governmental or monopolistic encumbrances or restraints," and (2) the taking of "bold steps" to assure that production of synthetics from coal and shale can be geared into the oil economy when the need arises.

We may not be able to fuel another large war from domestic sources right now, said the committee in effect, but with synthetic liquid fuels to fall back on "it is folly to be apprehensive that this nation is facing a shortage of liquid fuels."

Although the Iranian crisis was resolved, Middle East oil continued to hold the center of the stage. It had an insistent way of staying in the headlines. It was constantly insinuated into the Palestine situation.

Lurid headlines appeared in 1947 about alleged exorbitant oil prices charged the United States Navy by American companies in the Middle East. An inquiry into American investments and diplomatic commitments in the area was launched by the Senate (Brewster) War Investigating Committee.[125]

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[123] Report of committed headed by Congressman Clarence F. Lea, *Natl. Petroleum News*, Jan. 8, 1947.

[124] *Natl. Petroleum News*, Feb. 5, 1947.

Passions were stirred within the oil industry by the issuance of an export license for steel to begin construction of the trans-Arabian pipe line—this in the face of domestic shortages of pipe and oil-country tubular goods.[126] The Marshall Plan (European Recovery Plan) raised the question of what the recommended petroleum requirements under it would do to the domestic oil supply. In connection with it (and the Interim Aid Plan), it was brought out that the intention was to fill most of such requirements from foreign sources, this tending to justify the building of the trans-Arabian pipe line.[127] Moreover, a government policy "to save home supply" came out in the open. Said the *National Petroleum News* Washington bureau:[128]

"The 'political, economic, and strategic' reasons behind government support of Middle East oil development are now out in the open, including a firm declaration by the Navy that it favors the United States 'relying heavily' on imported oil in peacetime so that our own can be saved for some future war. Not only does the Navy advocate such a policy, it already has put it into effect, for one of the purposes behind current Navy purchases of Middle Eastern oil, said Undersecretary W. John Kenney, is 'to reduce the drain on our essential reserves' at home."

The oil "shortages" of the severe winter of 1947–1948—the Cold Winter oil scare (see pp. 378–391)—gave the Cold War oil scare support of a most sensational and urgent, if circumstantial, nature. It not only appeared to the man on the street as if we *might* run short of oil but as if we *had.* It was in this feverish climate that various projects for guarding and enhancing our oil supply, present and future, were promulgated in the name of security. Protection and encouragement of American interests and activities in the prolific Middle East oil region, development of a synthetic-liquid-fuels industry at home, and stock piling were among the actively supported policies.

One discovers, again, a variety of controversial projects and proposals riding the wings of an oil-shortage scare.

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[125] *Oil Gas J.*, Apr. 5, 1947.

[126] *Oil Gas J.*, Oct. 4, 1947; *Natl. Petroleum News*, Oct. 8, 1947.

[127] *Natl. Petroleum News*, Oct. 22, 1947.

[128] *Natl. Petroleum News*, Oct. 29, 1947.

When a bill was introduced in Congress to extend the synthetic-liquid-fuels research program of the U.S. Bureau of Mines for another three years at an additional cost of 30 million dollars, President Truman in his budget message sent to Congress Jan. 12, 1948, recommended extension of this activity, on the ground that "depletion of our petroleum reserves is one of our most serious and far-reaching problems.[129] The measure was passed and was signed by him on Apr. 15, 1948.[130]

Secretary Krug did not rest on mere support of the extension of the Bureau's research program. In his annual report to Congress, he went much further, proposing initiation of a gigantic synthetic-fuels industry.[131] Noting that domestic demand for petroleum was continuing to rise along with world needs, he said it was "clear now" that the United States could not rely exclusively on petroleum to supply all future requirements for liquid fuels and related products. It could not go on producing 63 per cent of world consumption from 31 per cent of world reserves. Production from known domestic fields was diminishing and "will continue to diminish as these fields are drained," he said.

Therefore, he recommended to Congress that a 5- to 10-year program—with government financial aid, if necessary—be launched immediately to create a synthetic-liquid-fuels industry capable of producing 2 million barrels daily. Production of liquid fuels from coal, lignite, and oil shale as proposed involves, of course, first the opening and operation of mines to get the raw material, then the building of processing plants or refineries.

As a starter, Krug proposed construction of three commercial-size plants, at the estimated cost of 400 million dollars, utilizing oil shale, the coal-hydrogenation process and the Fischer-Tropsch coal process, respectively. His long-range program to create 2 million barrels a day capacity would need 9 billion dollars. It would take 16 million tons of steel. He wanted immediate action in peacetime, as the establishment of a synthetic-fuels industry was "far too large an operation and requires too much time to be undertaken under emergency or war conditions." The program made the wartime synthetic-rubber program look puny. Krug said it would be ten times greater.

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[129] *Oil Gas J.*, Jan. 15, 1948.

[130] *New York Sun*, Apr. 15, 1948.

[131] *Natl. Petroleum News*, Jan. 28, 1948.

Synchronizing with Secretary Krug, Defense Secretary Forrestal advocated a similar program because of uncertain access to foreign oil in the event of a war.[132] Such a project, he conceded, would have a "dramatic impact" on the domestic economy in relation to its requirements of huge amounts of such vital materials as steel.

The 2 million barrel daily oil-deficiency figure in case of war which at this juncture was injected in the oil-shortage scare picture was based on military findings that oil requirements of the next war would be 2 million barrels a day more than the "foreseeable" domestic consumption.[133] (In 1946 Col. G. H. Vogel, executive officer of the Army-Navy Petroleum Board, stated that the early military oil needs in case of a possible future emergency were indicated to be more than twice the peak requirements of the Second World War, or 2.6 million barrels daily more.[134])

Representative Charles A. Wolverton introduced a bill to implement the Krug proposal for government construction of three synthetic-fuels plants at an estimated cost of 300 million to 400 million dollars.[135] Hearings were held before the House Interstate Commerce Committee. Representatives of the oil industry gave only qualified approval to the government's plan to develop synthetic-fuels production, believing that governmental participation should be limited to scientific cooperation and financial assistance. The oil industry itself, it was pointed out, had long engaged in extensive research on liquid fuels from coal, lignite, oil shale, and natural gas. It has spent nearly 30 million dollars during the past two or three years on such research, with present investigations costing at the rate of about 10 million dollars a year.[136] In general, the oil people said, synthetic-fuels development would come from within the industry as rapidly as economic conditions require. They thought Krug's program would cost more like 17 billion dollars than 9 billion dollars.

Where would the 16 million tons of steel come from? Where would the man power come from for mining operations to get the raw materials for a 2 million barrel a day production? Bruce K.

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[132] *Natl. Petroleum News*, Jan. 21, 1948.

[133] *Oil Gas J.*, Jan. 22, 1948.

[134] Zook, Ralph T., Looking Ahead, *Proc. Ann. Meeting Am. Petroleum Inst.*, Nov. 14, 1946.

[135] *Oil Gas J.*, Mar. 11, 1948.

[136] *Nat. Petroleum News*, Feb. 18, 1948.

Brown, chairman of the Military Petroleum Advisory Committee and the vice-president of the Standard Oil Company (Indiana), estimated that 468 million tons of coal per year—more than two-thirds as much as was ever produced in a single year would be required.[137] He said that first preference for steel should be given to producing liquid fuels from crude petroleum, so much less costly in man power and steel than the production of liquid fuels by any other method. When and if crude oil becomes sufficiently scarce to justify the necessary steps, Brown assured the congressmen, all of the liquid-hydrocarbon fuels that are really needed could and would be synthesized from natural gas and coal.

"The costs of a forced wartime development as a major substitute for natural petroleum would be fantastic . . . . A forced peacetime development using subsidy dollars is practically as difficult," he declared.

At the same time, Defense Secretary Forrestal raised the ghost of the PRC, telling the Senate War Investigating (Brewster) Committee that a direct stock acquisition by the United States government was one of the two "alternatives" open to us for protecting our oil interests abroad and bringing stability to the turbulent Middle East.[138] The other was negotiation of a contract to set aside, in the ground, a certain portion of Arabian oil reserves for delivery to United States armed forces at "a definite price for the future." Both moves, it will be recalled, were proposed by Secretary of the Navy Frank Knox and Petroleum Administrator Ickes during wartime. Forrestal admitted to the Senate committee that any such steps posed "a very important national decision." It would be a question of "whether the government is to go into the oil business," he explained.

Oil stock piling also came up for intensive discussion. During the Ickes' Arabian pipe-line scare the oil industry had called such proposals unsound. Indeed, stock piling of oil later was so generally considered impractical, even by military officials themselves, that when the Strategic and Critical Materials Stockpiling Act of 1946 was under consideration, they omitted that commodity from the act.[139] As the oil-shortage scare burgeoned, however, Secretary Forrestal let it be known that this ghost also was abroad again. The military were studying the possibilities of importing oil and putting it into underground storage, preferably in some natural reservoir, like a depleted oil pool, or in salt mines or limestone caverns, from which it could be withdrawn in case of need.

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[137] Before House Armed Services (Short) Subcommittee, *Natl. Petroleum News*, Feb. 4, 1948.

[138] *Natl. Petroleum News*, Feb. 4, 1948.

[139] *Oil Gas J.*, Feb. 12, 1948.

At hearings of the House (Short) Armed Service Committee, E. DeGolyer, consulting geologist, suggested the possibility of the government purchasing a whole proved field and capping it until needed.[140] Or the government might make a trade, taking over a field of some 100 million barrels proved reserves with a 40,000 bbl daily capacity and paying the owners in oil at that rate, preferably with foreign oil, he said.

Independent oil operators' mildest comment on stock piling was that it was "impractical." They charged the Administration with magnifying the fuel-oil situation to pressure Congress into accepting ideas which in quieter times it would immediately reject.[141] During the Ickes' Arabian pipe-line scare, the prohibitive costs and economic and physical impracticability of oil stock piling were brought out in the preliminary report of the National Oil Policy Committee of the Petroleum Industry War Council (1944).

The controversial tidelands oil case perhaps is not unrelated to the Cold War oil scare.

"It is the view of the national military establishment," Defense Secretary Forrestal told the House Armed Services Oil Subcommittee, Jan. 19, 1948, "that development of the tidelands area should proceed as rapidly as possible and that all necessary action should be taken to permit rapid development of those areas. Delays in the development of the oil potential of the tidelands is considered contrary to the best interest of the United States from the viewpoint of national security. I do not in any way condone or favor practices that are contrary to sound conservation principles, but I do wish to emphasize that undeveloped oil fields provide no power for the machines of either war or peace."[142]

Krug told a joint Senate-House Judiciary Committee that the Continental shelf off the United States and Alaska, comprising 759,200 sq miles, is estimated to contain 100 billion barrels of oil—if so, perhaps our most valuable oil reserve.[135] "The oil reserves in the continental shelves contiguous to the coasts of the United

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[140] *Oil Gas J.*, Feb. 19, 1948.

[141] Linz, Bertram F., *Oil Gas J.*, Feb. 19, 1948.

[142] *Natl. Petroleum News*, Mar. 10, 1948.

States are vital to the economy and defense of the United States as a whole," he declared. "The people of the United States cannot afford to make a gift of these tremendously valuable resources to a few coastal states."

Actually the title of the respective states to their tide- and submerged lands had been formally established for 100 years or more—until the United States asserted claim to title through various departments and agencies, filing its first suit in California in 1938.[18] During the war Secretary of the Interior Ickes became convinced that the Continental Shelf contained an immense oil reserve. President Truman proclaimed government dominion over the Continental Shelf in 1945. On June 23, 1947, the Supreme Court of the United States, in a new California tidelands case inspired by Ickes, found in favor of the Federal government's claim.[135] The decision was based on national security. Following this decision United States Attorney General Tom Clark announced plans to sue for the offshore lands "of Texas, Louisiana, and two or three other Gulf coast states" and later filed such a suit.

As opposed to this, legislation to restore the tidelands to the states was introduced in Congress early in 1948, and hearings were held. At one of these Secretary Krug, like Attorney General Clark, who preceded him, in effect threw the Continental Shelf into the oil-shortage-scare hopper by tying its gigantic (estimated) oil reserves into security, as had the President and the Supreme Court.

Former Secretary of the Interior Ickes told the joint Congressional committee studying the tidelands bill that he would have the offshore oil areas made a naval reserve.[143] Other Federal government officials shared this view, it was said. "Some industry observers felt that the anxiety of the Army and Navy over adequate oil supplies may lie in the background of the present tidelands dispute," said a trade-journal correspondent.[144] "A part of the pressure for Federal control [of the Continental Shelf], they think, is stemming from the military, particularly the Navy, which traditionally has held the oil-reserve philosophy. On the other hand, another group believes that the government's efforts are simply another attempt to extend and broaden Federal power and authority."

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[143] *Oil Gas J.*, Mar. 18, 1948.

[144] DUFF, DAHL M., *Oil Gas J.*, Mar. 18, 1948.

At this time, too, the economic impact of the new rearmament preparedness program was being felt, accentuating the shortage oil crisis.[145] Much of the expansion would involve greater oil requirements, as, for instance, increased aircraft production.[146]

Behind all the studies and discussions on synthetics and stock piling was the threat of loss of Middle East oil. What was the good of having a big Middle East oil production when Russia could walk in at will and take it away from us? Wouldn't it be wiser to bank on home sources or closely accessible petroleum supply and build up a stand-by synthetic-fuels industry? Subcommittee Chairman Dewey Short flatly expressed his belief that the Middle East supplies would be "cut off pretty soon."[147] And Representative Wolverton prepared a new synthetic-fuels bill by which private industry would be given an opportunity to build plants and assured of a profitable market and which provided for RFC financing.[148]

By this time, there was evidence of a shift of viewpoint of the military away from favoring the government's synthetics program as an immediate oil-security measure or from advocating one single project that might jeopardize another. Rather, as Colonel Vogel expressed it, the solution lay in a carefully balanced selection of the best among several plans, with industry carrying the major burden and government assisting only where expedient.[149] And opposing the legislation and asserting that "there is no basis for the claim that this nation is running out of oil," directors of the Independent Petroleum Association of America adopted a resolution against subsidization in any form of a synthetic-liquid-fuels industry as well as government ownership, operation, or control of commercial synthetic-liquid-fuels plants.[150]

Then came the result of months of testimony by over two score military and other witnesses—the report of Representative Short's House Armed Services Subcommittee, submitted on May 6, 1948. Almost hysterically it called for quick, drastic action to make the United States self-sufficient in oil before another war should overtake us.[151] It warned that a "grave" insufficiency of petroleum

[145] *The New York Times*, Apr. 2, 1948.

[146] *Natl. Petroleum News*, Mar. 31, 1948.

[147] *Oil Gas J.*, Mar. 4, 1948.

[148] *Oil Gas J.*, Apr. 8, 1948.

[149] *Natl. Petroleum News*, Apr. 14, 1948.

[150] *Natl. Petroleum News*, May 5, 1948.

[151] *The New York Times*, May 7, 1948; *Natl. Petroleum News*, May 12, 1948.

endangered the national defense. It recommended, in case of failure of existing programs, compulsory steel allocation and a revival of rationing of oil and petroleum products, also immediate stock piling, plus establishment of additional military oil reserves, 20 million dollars for continued oil exploration in Alaska, immediate development of the tidelands oil resources, postponement of the Arabian pipe line with the steel used instead for tankers, development of all possible resources in South America, and continued research on synthetic fuels, but not at the expense of current oil production.

It asked the President to direct the National Security Resources Board to establish a commission with representation from the oil industry, the consuming public, and government agencies which would recommend to Congress a "fully rounded oil policy adequate to meet the nation's present and long-range needs."

Saying that "we cannot fly jet air fleets on undiscovered oil," it estimated that, in the event of war, the country would be almost 3 million barrels a day short of its war requirements. It found that domestic consumption had mounted so rapidly that the "fat" of our prewar productive capacity had been consumed. "We are now scrounging along as best we can, with the future promising that our present peacetime petroleum difficulties will not be improved but, on the contrary, will be aggravated," it said.

"We already have found well over half the crude oil we can expect ultimately to find in the United States." it added. "Only about a 12-year supply of oil remains. Our known oil reserves are less than one-third of the known reserves of the world, but they are being consumed at a rate of 63 per cent of the world's output."

This report, perhaps, marked the climax of the Cold War oil scare. It brought the following comment from the *Oil and Gas Journal* in an editorial headed The Military Viewpoint:[152] "Much of the public alarm as to oil supplies has a military source."

Even as Representative Short was penning his report, there were definite signs that, despite his prediction of continued and aggravated "oil-shortage" difficulties, they were rapidly being overcome. President Truman turned down the Subcommittee's proposal for the National Security Reserves Board to appoint a commission. Later a report on national oil policy, prepared by the National Security Resources Board in consultation with representatives of the military and other departments, expressed confidence in the ability of the oil industry to meet all needs provided that it was kept strong and free.[153] It called for development of synthetic fuels by the government on an exploratory basis only, with a few commercial-size plants to demonstrate the feasibility of synthetic production.

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[152] *Oil Gas J.*, May 27, 1948.

By this time, the Cold War oil scare was definitely in retreat before the forces of oil plenty once again recruited by the industry.

7. THE COLD WINTER SCARE—1947–1948

First warnings of possible coming fall and winter "oil shortages" in 1947–1948 were recorded as early as the spring of 1947, when two important "supply and demand committees" presented reports to the Interstate Oil Compact Commission, focusing attention on the unprecedented demand for petroleum products.[154] The rapid increase in consumption, and difficulties facing the industry in meeting it, was the chief topic of discussion at a quarterly meeting of the National Petroleum Council on Apr. 22.[155]

Could supply keep pace? Would there be enough crude oil? Would there be sufficient pipe line and other transport facilities to move it to refineries? Could products be made fast enough? Would there be enough refining capacity? Would there be sufficient tankers, tank barges, and trucks to move the products to consuming points, however accessible or inaccessible? Could every need of motorists, homeowners, ships, railroads, and all other users be supplied? These were some of the questions asked within the industry. It was competing with other industries for steel. It would have to get more steel for drilling, pipe lines, tankers, refineries, and other necessary equipment.

All in all, less concern was felt about adequacy of supply than of transportation. Transportation would be the bottleneck, it was forecast.[156]

Postwar demand was phenomenal—there had never been anything like it. On second thought, there were precedents—in 1914 to 1916, when Henry Ford launched the car for the multitudes, (the days of the Model T scare), and in the early 1920's, when demand by automobiles and ships pyramided (the days of the John Bull scare).

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[153] *Oil Gas J.*, Apr. 14, 1949.

[154] *Natl. Petroleum News*, Apr. 30, 1947.

[155] *Oil Gas J.*, May 3, 1947.

[156] *Natl. Petroleum News*, June 11, 1947.

In fact, the similarity of situation in the postwar era of the Second World War and that of the First World War is striking. As Ford's "tin Lizzie" and other cars hit the road after the First World War, motor-fuel consumption actually rose 100 per cent between the years 1919 and 1923 and over 200 per cent above 1914, when the war started. Fuel-oil consumption, mainly because of the advent of oil-burning ships and the growth of industrial and advent of home oil burners, increased 128 per cent in the period 1914 to 1923.

In 1947, consumption of all oil products made and sold by United States refineries was almost 50 per cent greater than in 1941, and in volume this meant a fantastic increase as compared with the increases of the 1920's. At the end of 1947 there were some 35 million motor vehicles on the road.[157] In the one year passenger cars, motor trucks, and busses increased 5.6 per cent and would have gone much higher had the automobile industry been able to meet the demand.

Mechanization of farms took on a big spurt, called for more petroleum products. There was an increase in motor tractors in use in the one year of 6.4 per cent.

As efforts were made to meet the call for housing and shelter, the demand for oil space heaters and automatic oil burners was so great that in this one year over 1.5 million of the former and over 700,000 of the latter were installed, with an estimated 5.5 million homes having oil space heaters and 3.7 million having automatic oil heat at the end of 1947.[158] This represented a growth in one year of 40 per cent in space heaters and 19.7 per cent in oil burners —and the consequent heightened demand for kerosene, distillates, and fuel oil.

A spectacular shift from steam to diesel-electric locomotives by American railroads occurred. Ninety-five per cent of all new locomotive orders early in 1947 were for diesel-electrics. The number in use increased 25.9 per cent that year.

This indicates the variety, extent, and scope of the pent-up demand for oil-consuming products that challenged the oil industry in 1947. Indeed, it was realized in the industry that a change comparable with the switch early in the century from kerosene to gasoline as the principal product of petroleum was taking place. Distillate, burning oils, and diesel fuels were beginning to challenge gasoline for top consumer favor. As expressed by Walter S. Hallanan, president of the Plymouth Oil Co. and chairman of the National Petroleum Council (NPC), the industry was passing through a significant change—a shift to an economy dependent jointly upon gasoline and distillate fuels.[125] Demand for distillate, burning oils, and diesel fuels, he pointed out, was expanding much more rapidly than for gasoline.

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[157] *The New York Times*, Feb. 1, 1948.

[158] Fanning, Leonard M., "Rise of American Oil," Harper & Brothers, New York, 1948.

As consumption of distillates in homes was largely seasonal—a cold-weather matter—the tight supply and transportation shortages might mean trouble during the coming winter. At this point, everyone began to pray for a mild winter.

It was Max W. Ball, director of the Interior Department's Oil and Gas Division, who emphasized that the severity of any shortages would depend on several "ifs"—if the maritime strike did not extend to tankers, if there were no other serious prolonged strikes, and *if there were no long spell of cold weather.*[159] Indeed, the Cold Winter scare, as we have chosen to call it—which ran concurrently with the Cold War scare—might better be termed the "If" scare, so important, as it turned out, was that last "if" factor.

There was even some question about the industry's ability to meet fully all the needs of motorists before the big driving season was over. An interagency meeting was called by Interior Secretary Krug to find ways to ease the impact of expected shortages and was attended by Secretary of State George Marshall, Presidential Assistant John G. Steelman, Undersecretary of War Kenneth C. Royall, Undersecretary of the Navy John L. Sullivan, and Edgar L. Warren, director of the United States Conciliation Service.[159] At its conclusion, Krug said gasoline shortages were threatened in the fall in some regions, especially the Middle West, and that a scarcity of fuel oil and natural gas might follow in the winter. In addition to causing personal discomfort, this could lead to the shutting down of industries and could also adversely affect the European economy, he declared.

The maritime strike and the steel shortage were raised as major threats to the outlook which would be intensified, he warned, unless the government's tanker charter rights were extended. He said that, while there were grounds to fear that local shortages would develop, there was "no basis for hysteria." In this connection he urged the public not to hoard gasoline and added that the government was not thinking of a return to rationing.

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[159] *The New York Times*, June 18, 1947.

First sign of an actual gasoline pinch came when Standard Oil Co. (Indiana) announced a gasoline allocation program, entailing informal rationing for some filling-station operators in the Middle West.[160]

"Oil Crisis Looms" headlines accompanied announcement of the Army-Navy Petroleum Board that the Army and Navy faced an acute shortage of aviation gasoline as a result of the oil industry's failure to bid to fill the services' needs[159]. Spurred by criticism of oil shipments to Russia, the Office of International Trade (OIT) of the Department of Commerce reinforced wartime controls on exports of petroleum products.[161] This was an initial move, which was successful, toward the extension of the emergency law authorizing such export regulation and requiring shippers to obtain licenses. It followed closely the establishment of Presidential committees to study the effect on United States resources of the Truman Doctrine and the Marshall Plan. Pointing out the greatly increased civilian requirements for gasoline, fuel oil, and other petroleum products and the "substantially unfilled Army, Navy, and other state and Federal needs, OIT stated that "export control is necessary if the limited domestic supply is to be protected and United States exports are to be used most effectively." But, it added, export control would not "solve the domestic oil shortage alone" and urged the American people to follow conservation measures.

The Navy Department's disclosure of an acute shortage of aviation gasoline soon developed into a "situation of robust proportions."[162] From Houston, a charge was made by H. J. Porter, president of the Texas Independent Producers and Royalty Owners' Association, that Army and Navy officials and representatives of some government bureaus were attempting to stampede public opinion into believing the country was dangerously short of crude oil.[162]

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[160] *Chicago Tribune*, June 25, 1947.
[161] *The New York Times*, June 24, 1947.
[162] *The New York Times*, June 29, 1947.

By the end of June an oil-shortage scare, showing most of the familiar symptoms—including a mushrooming of Congressional investigations—was definitely "on the loose" again. These "scare" developments drew the following comment from the *National Petroleum News*:[163] "The oil industry's supply and demand problem is getting bigger and blacker headlines in the nation's newspapers and more space in the *Congressional Record* this week, but the industry itself feels that the situation is basically unchanged."

The industry was doing everything possible to combat the tight supply and demand situation. Throughout the war crude-oil prices had remained stationary, with representative mid-continent crude at $1.17 a barrel. This was in spite of pleas of Petroleum Administrator Ickes and the oil industry for an increase to encourage wildcat operations. Advancing prices after the First World War (mid-continent crude went up to $3.50 a barrel) stimulated development and exploratory drilling, as we have seen. In 1946, the end of OPA ceilings was followed by advances in crude-oil and petroleum-product prices. As for gasoline, the average price rose from 14.1 cents in July, 1946, to 17.8 cents in December, 1947. As in the case after the First World War the natural economic manifestation—advancing crude-oil prices because of tight supply—stimulated more drilling. As prices rose now—from $1.17 to $1.87 a barrel (the price went up to $2.57 in April, 1948)—new records in production were made in 1946 and 1947.

Oil operators completed the near record of 33,098 wells in 1947 despite acute shortages of steel. That was exceeded only by 1920's all-time record of 33,972 completed wells.[164] They produced an all-time high of 1,896,679,000 bbl, an increase of 7.8 per cent over 1946. They stepped up their exploratory campaigns to the highest level in the history of the industry. Going far out into rank wildcat territory and at the same time continuing their search of the older, more proved areas, they completed a record-breaking total of 5,461 exploratory wells, an increase of 17.3 per cent over 1946. Also, better than average success attended the search for new oil, with 20.6 per cent of the wells rated as successful in finding oil or gas.

[163] *Natl. Petroleum News*, June 25, 1947.

[164] *Oil Gas J.*, Jan. 29, 1948.

New fields were discovered, old fields extended, adding to proved reserves. During the year which had seen 1.8 billion barrels taken from the ground in the United States, there was an addition of over a half billion barrels to proved reserve, bringing the total to a new high figure of almost 21.5 billion barrels.[165]

In 1947 the industry launched a 4-billion-dollar two-year expansion program.[166] Virtually the only limitation on this immense program was inadequate supplies of steel and other construction materials—a factor bedeviling most industries—and the petroleum industry was making aggressive efforts to obtain larger allocations of supplies from steel companies. Its two-year expansion called for estimated expenditures of 2 billion dollars to increase exploration and drilling facilities; 1 billion dollars for refineries; 500 million dollars for new pipe lines, tankers, tank barges, tank cars, and tank trucks; and 500 million dollars for distribution and marketing equipment. By late in 1947 construction of about 450,000 bbl daily additional refining facilities and almost 13,000 miles of new pipe lines was well launched.[167]

Refinery runs in 1947 reached new high records; production of gasoline rose 7.1 per cent, kerosene 10.8 per cent, distillates (heating oils) 17.6 per cent, and residual fuel 7.7 per cent over 1946.[157]

Yet with all this effort local "spot" shortages were occurring, largely because of transportation shortages and bottlenecks.

The conduct of the Senate Small Business Subcommittee's investigation into oil-products shortages in the Middle West by Senator Kenneth S. Wherry of Nebraska caused the *National Petroleum News* to doubt the value of its hearings[168] and drew this comment in the *Oil and Gas Journal*:[169] "[The committee] which is holding hearings in Chicago can serve the best interests of millions of consumers and the oil industry itself if it will drop politics and conduct an investigation from which comprehensive and constructive conclusions are possible. Up to now the hearings have amounted nothing more than another smear at the oil business."

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[165] American Petroleum Institute, February, 1948.

[166] "Current Facts on Petroleum Supply and Demand," American Petroleum Institute, November, 1947.

[167] *Oil Gas J.*, Sept. 20, 1947.

[168] *Natl. Petroleum News*, Sept. 3, 1947.

[169] *Oil Gas J.*, Aug. 30, 1947.

A *National Petroleum News* staff writer wrote:[170]

"Senator Wherry's Oil Subcommittee hearings have served only to focus public attention on the obvious problems arising from any tight supply situation. They have failed, however, to bring to light those contributing factors which magnify otherwise normal problems and make those problems hooks upon which an investigation committee may hang its placards heralding the great public service it is rendering.

"At Chicago, Omaha, and Kansas City, testimony at hearings showed that spot shortages have developed—as oil-industry economists predicted they would. In this respect, the hearings only served to reiterate a fact of which the industry already was aware. Also, in reiterating these spot shortages through testimony and by inferential questions fired by the Senator at witnesses, the daily press was given a picture of a monopolistic industry determined to eliminate the small businessman from competition."

The Maritine Commission had tankers tied up out of service, release of which it was contended would help relieve the shortages. Governors of affected states, mayors of affected cities chimed in with the voices of Congressional representatives in demanding supplies as the winter advanced. Many beat a path to Washington to urge Federal action. On Jan. 17, President Truman ordered temperatures in all government office buildings and other establishments, including residences, to be held down to 68° to save fuel oil and placed a 40-mile speed limit on government vehicles in order to save gasoline.[171] Many oil companies announced they would fill requirements only of old, existing customers, thus discouraging installation of new oil burners.

In contrast to the methods of Senator Wherry, Senator Charles W. Tobey of New Hampshire, whose Senate Banking and Currency Committee also investigated the oil situation, asked the oil industry, as best qualified, to advise the committee how local supply problems could best be licked. As a result state governments, following a recommendation made by the industry, were soon setting up state-sponsored organizations and appointing fuel-oil coordinators, and the industry was making a vigorous plea to its heating-oil customers to conserve.[172] By the middle of January, 18 states had named coordinators, and 4 named special committees.

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[170] RIDDER, HOLGER, *Natl. Petroleum News*, Oct. 8, 1947.

[171] *The New York Times*, Jan. 18, 1948.

[172] *Natl. Petroleum News*, Jan. 14, 1948.

One of the first acts of the new Congress in December was to pass the Taft anti-inflation act authorizing the government to cooperate in the allocation of short supplies through voluntary agreements. Secretary Krug asked the NPC to appoint a committee to help the government carry out the purposes of the new law as they applied in the oil industry. This results in a committee headed by Dr. Robert E. Wilson, chairman of the board of the Standard Oil Company (Indiana).[173] On Jan. 22, the NPC adopted the report of this committee, which codified proposals that had been urged and to some extent adopted and which became the basis for government-industry-public cooperation.[174]

After the Department of Justice gave the oil industry the green light for its cooperating plan, and with the approval and cooperation of the Interior Department's Oil and Gas Division, the voluntary allocation program was set in motion. The main points of the over-all program were cutting back refinery products of gasoline for 60 days in order to make more fuel oil; pooling and allocation of oil products in some areas to save transportation and overcome local shortages; limiting exports "to the extent possible consistent with over-all necessities of our international relationships"; checking the demand for fuel oil to "more nearly balance with the industry's production"; and adoption of conservation measures by fuel-oil consumers and by gasoline users as well.[157]

"The extent of success of the oil industry's program depends chiefly on two factors: the cooperation of the weather and of the oil-consuming public," said a writer in *The New York Times*.[175] The weather was uncooperative. In the heavily populated northern areas it was one of the severest and longest winters on record. The industry's all-out efforts to manufacture enough fuel oil, supply transportation for it, keep transportation going in ice-clogged rivers, and make delivery over snow-piled and icy roads fell somewhat short of filling the needs of every customer at all times. Nevertheless, if Oil and Gas Division Director Ball's cold-spell "if" had not materialized—if the winter had been a normal one instead of one of the bitterest—it is quite reasonable to believe that the greatly expanded fuel-oil production and distribution efforts of the industry would have fully met the situation. Charting the "degree-day" variations from normal to show how badly

[173] *The New York Times*, Jan. 12, 1948.

[174] *World Petroleum*, February, 1948.

[175] WHITNEY, ROBERT F., *The New York Times*, Feb. 1, 1948.

the weatherman treated the oil industry, the *National Petroleum News* declared[176]: "Had this winter been normal; it is very possible that the public would not have known that there was a tight fuel-oil situation."

That some home fires were not kept fully burning had the effect of fueling the "shortage hysteria," causing the oil industry's positive achievements in keeping actual hardship cases to a negligible percentage to be generally overlooked and leaving the shortage scare very much abroad.

For months the "oil shortage" got millions of dollars' worth of free publicity—bad publicity. A survey made in 26 states and the District of Columbia between Feb. 17 and 28, 1948, revealed that "the fuel-oil supply problem is worrying the public more than the shortage of any other commodity," that the fuel-oil "shortage" had made a deeper impression on citizens than any other national shortage except housing.[146] Concerned (and sometimes opportunistic) politicians all the way from community to national levels muscled in on it in behalf of their "freezing" oil-burning constituents.

"Oil-shortage" fear was not alleviated by Ball when he said that the fuel-oil situation would probably "be equally bad next winter" before it became progressively better.[177] In fact, he saw no present prospect that the oil industry, no matter what it did, would be able to get back to normalcy within less than three to five years. Nor did Defense Secretary Forrestal help when he told the House Armed Services Subcommittee that the military viewed the oil situation of the United States with very great concern; indeed, that the outlook was so dark that experts had advised him that the four-cylinder automobile might have to come back.[132]

It was brought out that Interior Secretary Krug and other officials in Washington felt that the over-all shortage of petroleum products might endure for three or four years, and their recommendations for a cut in consumption were addressed "to the long term as well as to the present and immediate future."[157]

Comment out of Washington in November, 1947, was to the effect that Congress was working itself into a "dither" over the "oil shortage."[178] If "dither" was the case in November, in Janu-

[176] *Natl. Petroleum News,* Feb. 25, 1948.

[177] Testimony before the House Interstate Commerce Committee, *Oil Gas J.,* Dec. 20, 1947.

[178] *Natl. Petroleum News,* Nov. 26, 1947.

ary and February and during the balance of one of the country's toughest winters, (as oil-burning constituents "froze" from lack of oil fuel) it may be said that Congress was in a perpetual oil froth. One oil writer called it "oil hysteria."[179]

Many of its legislative manifestations are reminiscent of the Model T scare and the John Bull scare. Representative John W. Heselton of Massachusetts offered a resolution for a 60-day oil-export ban.[131] Senator Styles Bridges of New Hampshire introduced a bill for a complete export embargo. While this brought forth comment from the Commerce Department officials that such an act would "be jeopardizing the success of the Marshall Plan" and might cause Caribbean countries "now our main sources of foreign oil supply" to take similar action against us,[180] nevertheless, the House Committee on Interstate and Foreign Commerce, of which Representative Wolverton of New Jersey was chairman, recommended a complete halt "until it can be determined whether further exports are damaging to the economy of this country."[131]

The same (Wolverton) committee, accusing both the oil industry and the government of not giving the problem of current and prospective oil-supply shortages "the energetic attention it deserves," declared that the time was at hand for Congress to undertake the job.[131] With "the present and future security of the people of the United States" threatened, it said: "The Committee does not believe that we are forced to accept the panaceas which so far have been offered to us by government and industry, namely, the cheerful acceptance by the consuming public of the inevitability of these tight situations; the leaving to industry to work out, without governmental interference, this problem, which for some time now they have assured us would not arise and the solution to which they so manifestly so far seem unable to reach; or acquiescence to the superficial remedy suggested of allocating or rationing available supplies without maximum effort to effectuate a real cure through bringing supplies and demand in line.

"Let Congress immediately create a 14-member special House-Senate committee charged with formulating and recommending a national fuel policy adequate to meet the needs of the United States in times of peace and war." An enabling resolution dropped in the hopper by Representative Wolverton provided that the special committee's recommendations should also include those "for a national petroleum policy and the integration of such policy with policies relating to other fuels and energy resources except atomic energy." For purposes of the investigation, a second resolution proposed appropriation of $100,000 to the committee.

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[179] Yocum, Herbert A., *Nat. Petroleum News*, Feb. 4, 1948.

[180] *The New York Times*, Jan. 29, 1948.

Another bill, introduced by Representative Heselton, proposed control similar to the Interstate Commerce Commission (ICC) regulation of railroads.[181] It would set up a national petroleum commission of 11 members appointed for seven-year terms, which would take over all functions now possessed by any government agency with respect to the regulation of transportation or sale of petroleum and petroleum products, including natural gas. The commission would have authority to prescribe "such prohibitions and requirements with respect to the production, refining, distribution, and sale" of oil and oil products and natural gas as "it deems necessary for the protection of the national security and economy."

Oil-industry spokesmen were quick to point out that the ICC regulation of the railroads had not prevented a shortage of rail transportation, that Federal Power Commission regulation of interstate transportation of natural gas was not saving consumers from a shortage of natural gas this same winter in a great area of the country, north of the Ohio River, and quoted from Undersecretary of the Interior Chapman's address before the annual meeting of the American Petroleum Institute in November, 1947, as follows[182]:

"Mandatory controls increase cost, slow down service, and generally interfere with the normal fluidity of competitive business, which naturally finds and supplies new and unusual demand and, just as naturally, shuts off supplies where they are no longer needed. Not only that, but any such interference with the normal trade practices creates further areas of hardship and demands for still further interference."

Although Representative Heselton pigeonholed his bill, he at the same time threatened to press it in the future if the industry failed to meet "the challenge of providing supplies at reasonable prices."

Chairman Wherry of the Senate Small Business Oil Subcommittee asked the President temporarily to suspend the Connolly "Hot

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[181] *The New York Times*, Feb. 17, 1948; *Oil Gas J.*, Feb. 19, 1948; *Natl. Petroleum News*, Feb. 18, 1948.

[182] *Natl. Petroleum News*, Feb. 18, 25, 1948.

Oil" Act.[142] This act is what might be termed one of two basic Federal measures behind oil proration or conservation by the oil-producing states as practiced today in the United States. The other is the Interstate Oil Compact Act. Both have been on the statute books since 1935. He wrote: "The Committee is of the opinion that the shortage of petroleum has been used by the large integrated oil companies to expand their own direct operations to the detriment of Independent distributors; that it has been used by them to bring about unreasonably high prices for petroleum products; and that there has been manipulation of crude-oil production and transportation facilities to bring about these results."

It was "mandatory" for the White House to suspend the Connolly act, he said, because there was "a lack of parity" between supply and demand. He quoted a provision from law giving the President the power to make the act inoperative upon determination that production was "so limited as to be the cause, in whole or in part," of short supplies. Previously, Paul Hadlick, the Committee's special counsel, had charged that the short supply of fuel oil was man-made and could be overcome by relaxing, or even discontinuing, state restrictions on production, and this was the crux of Wherry's demand.

The Wherry proposal brought immediate protests from state officials. Colonel E. O. Thompson, chairman of the Texas Railroad Commission, declared that suspension of the Connolly law would not bring one more barrel of oil to the surface in his state. Governors and conservation experts in other oil-producing states concurred with Colonel Thompson, saying that their states were producing crude oil at maximum efficient rates at all wells from which there was transportation to move it.

As to Wherry's proposal to throw the Connolly "Hot Oil" Act, and with it proration, out of the window, one has but to recall the early 1930's after East Texas came in. The market was flooded with cheap oil, the producers selling this valuable, irreplaceable commodity at a few cents a barrel. East Texas producing methods violated all the rules of conservation. The Connolly act to regulate in interstate commerce the shipment of oil illegally produced was adopted to stop this waste. Senator Wherry apparently believed that, if the Connolly act were lifted and no such support given the state conservation laws, the states would have to increase their "allowables" (quotas of production) or be swamped by violations which they could not check, in either case permitting the production of more oil.[183] That is, he would have opened the spigot wide even at the expense of the maximum efficient rate of production. To meet existing local shortages of oil, to get an immediate flood of oil, he apparently would have scrapped the whole structure of present-day oil operation and conservation built up through years of experience.

President Truman denied Wherry's request, saying suspension of the act would result in "possible encouragement of production and interstate shipment of contraband oil in violation of state laws." And on Apr. 2 Secretary Krug said it was "practically the unanimous opinion" of private and government experts that state allowables were not too low but were "too high in some areas" to get the maximum production over the long haul.[184]

During the building up of the Cold War scare and the concurrent Cold Winter scare, at least 17 Congressional committees inquired into the oil situation and the oil industry in its various phases.[146] The House Interstate Commerce Committee issued a 159-page report on petroleum prices and profits, concluding with the statement that it was not prepared at that point to say whether "current prices are in the public interest."[152] That question, it said, "can be answered only within the framework of a national fuel policy, which has to be formulated against the background of the nation's economic and security requirements."

Although Congress made plans for continued oil studies during its recess, on adjournment June 20 it left unfinished a number of pieces of legislation which had made fervid debate and bold headlines. Among them were the tidelands bill, and the McCarran-Wolverton synthetic-liquid-fuels bill.[185] Oilwise, the outstanding feature of the session of the Eightieth Congress was the general deep interest of members of Congress in petroleum matters and the unprecedented number of committee investigations. Of the 17 odd committees which dug into one phase or another of the oil situation, most of them were concerned with the winter's fuel-oil "shortage," the possibilities of another coming up the next winter, and the industry's steel situation and exports; the European re-

[183] *Oil Gas J.*, Mar. 25, 1948.

[184] *Natl. Petroleum News*, Apr. 7, 1948.

[185] *Natl. Petroleum News*, June 23, 1948.

covery program, the military situation, and appropriations all had offered opportunities for committee studies of oil.[186]

8. Winning the "Battle of Supply"

At last the ruthless winter of 1947–1948 was over. Fear had been expressed that, because of gasoline-output cutbacks in favor of fuel oil, there would be gasoline shortages at the start of the 1948 motoring season.[187] But week after week in 1948 new records in domestic production and in refinery output were made, throwing into the limbo of the past those established the previous year.

Was the oil industry winning the "battle of supply"? M. J. Rathbone, president of Esso Standard Oil Company, thought so.[188] He saw "temporary" gasoline and fuel-oil shortages here and there, but none of serious proportions. Max Ball was telling an assemblage that, barring a "shooting war," the American public in the years ahead would receive a more abundant supply of better petroleum products at lower relative costs than it has ever known.[189]

Referring to statements that the petroleum supply would never again be abundant and that the world demand would grow too fast for even industry to satisfy, he declared: "Such predictions ignore economic history, discount the vigor and enterprise of the petroleum industry, and underrate the driving force of competition. I see nothing wrong in the petroleum situation that time and the normal operation of competitive forces will not cure, if the normal competitive forces are permitted to operate."

And Secretary Krug relaxed to the extent of saying that, while there might be local supply difficulties during the 12 months ahead, it was not anticipated that these would be "of sufficient magnitude to warrant the imposition of government control over the supply and demand of petroleum.[190]

On June 3, Eugene Holman, president of the Standard Oil Company (New Jersey), told the National Press Club at Washington: "Putting it plainly there is no crisis in oil. . . . The need of present consumers will be met, and there will be a margin available for a reasonable number of new users. I say this while fully aware of the great amount of attention being given to supply difficulties, and also knowing that some people accuse me of being an optimist on the supply situation. I think there is a great deal to be optimistic about. Drilling activities are up 18 per cent over last year, the country's oil-production rate is getting higher week by week. Already it is 7 per cent above the average for last year." He expected "all heating-oil demand for the next winter to be met."[191]

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[186] *Oil Gas J.*, June 17, 1948.

[187] *The New York Times*, June 30, 1948.

[188] *Natl. Petroleum News*, May 8, 1948.

[189] *The New York Times*, May 7, 1948.

[190] *Natl. Petroleum News*, June 2, 1948.

By the middle of June, motorists were being advised to go ahead with their summer tours.[186] Refinery crude-oil runs had increased phenomenally, averaging 5,656,000 bbl daily for the six weeks ending June 5, a gain of 667,000 bbl daily over the corresponding period the previous year. Because of this and refinery expansion, gasoline stocks were 12 million barrels over early June, 1947. Transportation, a bottleneck a year and two years before, was rapidly being corrected by the greatest pipe-line building program in oil history. New records were being made in the number of wildcat and development wells drilled. Increases in transport—availability of more tankers—also was a factor in the balancing of supply with demand.

On June 18, the industry's voluntary allocation plan which was up for renewal was given a public hearing.[192] Opposition was voiced by Chairman Ploeser of the House Small Business Committee on the ground that there were "conflicting opinions" as to whether a genuine shortage of oil existed.[193] Unless there was a "substantial existing scarcity," the proposed plan was "unnecessary and without benefit," he said. But on July 1 Chairman Reed of the Senate Commerce Oil Subcommittee was saying that, if oil supplies lagged further behind consumer demands, the government would have "to go to end-use controls."[194] He recommended that emergency fuel coordinators' offices be activated immediately in all 48 states. He also said he was writing governors asking that they consider establishment of a maximum speed limit of 45 miles an hour for automobiles and trucks as a gas-saving measure.

By the end of June the industry's ability to cope with the oil-supply situation, both "now and in the coming winter," was viewed "with cautious but definite optimism" both by government officials and industry spokesmen.[187] Ball told a joint Congressional committee that record stocks were on hand; he expected no summer gasoline shortage, and except for some isolated "trouble spots" fuel-oil prospects appeared better than the previous winter. Howard W. Page, executive assistant to the president, Standard Oil Company (New Jersey), said increases in domestic output, in addition to mounting imports, fostered the probability that the industry would "be out of the woods next year."

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[191] *Oil Gas J.*, June 10, 1948.

[192] *Oil Gas J.*, July 15, 1948.

[193] *Natl. Petroleum News*, June 30, 1948.

[194] *Natl. Petroleum News*, July 7, 1948.

In July, instead of the Oil Crisis Looms which met the eyes of motorists at the beginning of the previous summer, the headlines read Oil, Gas Supplies Set Records.[195] On Aug. 17, the *Oil and Gas Journal* released an article headed Oil Shortage Over,[196] which was carried in the press throughout the country.[197] It said that an analysis of the industry's statistics showed that "there is plenty of gasoline for the remainder of the touring season, and there are ample supplies of heating oil in all parts of the country for next winter."

Official Washington received the news with varying reactions.[198] President Truman stood firmly behind a prediction of the inevitability of a shortage of fuel oil on the east coast.[199] One of the several oil investigating committees had just issued warnings of such shortages, although conceding that the petroleum outlook for fall and winter "appears somewhat more favorable than last year."[199] Commenting, the *Oil and Gas Journal* said[200]: "The trouble with government in oil is that the industry moves faster than legislative committees, and their ponderous findings in analyzing current conditions after a prolonged investigation have historical value, but that is about all."

On Aug. 12, the industry's voluntary allocation plan, approved by the Attorney General and designed to avoid hardships should local product shortages occur during the winter heating season, was put in effect by the Secretary of the Interior.[196] It permitted adjustment of refinery yields to prevent disruptions in supply at the customer level and for purchases, exchanges, loans, transportation agreements, and the like, in the distribution of products to prevent, eliminate, or alleviate hardships. Supervision of this program was to be in the hands of district committees of the NPC. Its termination date was Feb. 28, 1949. The voluntary plan was identical in all its essentials with that successfully employed during the previous winter. Meantime, no motorist had to worry about getting gasoline.

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[195] *The New York Times*, July 31, 1948.

[196] *Oil Gas J.*, Aug. 19, 1948.

[197] *The New York Times*, Aug. 18, 1948.

[198] *Oil Gas J.*, Aug. 26, 1948.

[199] *Oil Gas J.*, Sept. 2, 1948.

[200] House Commerce (Wolverton) Committee Report, *Natl. Petroleum News*, Aug. 18, 1948.

So improved was the crude-oil supply situation that an increase in the price of crude oil by one company on Sept. 28 met resistance, and on Oct. 23, some of the companies that followed returned to lower price schedules.[201] When winter arrived, prices of fuel oil and diesel oil began to decline. Definitely the Cold Winter scare was over.

How the Oil Supply Problem Was Licked was the topic of an address by Dr. Wilson, who headed the NPC special committee on the allocation agreement, at the API's annual meeting Nov. 9.[202] Declaring that competition primarily and cooperation and conservation by all concerned had won the battle against the "superdemand" for petroleum and petroleum products, he praised government cooperation in aiding the industry's voluntary program, at the same time saying that, had the government stepped in and started pooling and rationing scant supplies, "all incentive for rival companies to outdo each other would have died."

Addressing the same meeting on the following day, L. F. McCollum, president of Continental Oil Company, submitted the Report on the Long-term Availability of Petroleum covering a five-year period 1949 to 1953 by a Subcommittee of the API National Policy Committee, of which he was chairman, which said: "The study shows that petroleum liquids from natural sources will be available within the United States in substantially increasing amounts. . . . In short, this nation can continue to grow through the use of petroleum products as a major source of energy."

Said McCollum: "Gentlemen, you have been hearing a lot of loose talk lately to the effect that America is running out of oil. . . . The fact is that these statements appear to be preposterous as those dire predictions made repeatedly for almost a hundred years."

After having expressed fears as late as Nov. 19, of a recurrence of the shortage of heating oils, Krug early in January admitted that "for the first time" there would be an adequate supply for

[201] *Oil Gas J.*, Oct. 28, 1948.

[202] *The New York Times*, Nov. 11, 1948.

the winter. At the same time he advocated his synthetic-liquid-fuels development program on the ground there had been no great improvement in the long-range picture, with supply and demand in approximate balance, hence "precarious."[203] But on the day before his second-term inauguration, President Truman revoked his order of Jan. 17, 1948, which prohibited new oil-burner installations in government buildings and banned conversions from coal to oil, placing himself publicly on record as to the "gratifying improvement in the general fuel-supply situation."[204] And at the termination date of Feb. 28, 1949, Secretary Krug permitted the allocations agreement to lapse.[205] Users of oil burners could get delivery on all the oil they needed that fall and winter. There was no hardship—no scarcity. The winter was mild in most of the heating areas. The fuel-oil coordinators had nothing to do.

In contrast to the advice to users of a year before, homeowners and others were encouraged to proceed with installing new oil burners or replacing old ones. "For the millions of householders who have been using oil burners in their homes," said an API news release dated Mar. 23, "and for the additional hundreds of thousands who plan to install them in the future, there is a strong note of reassurance and optimism in the current position of the petroleum industry's reserve supplies of distillate and residual fuel oils. With the current heating season approaching an end, storage supplies of these basic fuel oils are in their strongest position in years. In the wintry months of the 1948–1949 heating season, there was —and still is—plenty of fuel oil for all comers. At no time during this period was there any concrete reason for homeowners to worry about their current supplies of fuel oil."

It seemed as if almost in one year—not three to five, as some had predicted—the oil scare had been put to flight. Both the short-term and the long-range supply picture showed phenomenal improvements. Proved United States reserves of crude-oil and natural-gas liquids rose more than 2 billion barrels in 1948, the biggest one-year increase since 1937, with crude-oil reserves standing at 23,280,440,000 bbl compared with 21,487,695,000 bbl in 1947, an increase of 1,792,759,000 bbl.[206] Production topped 2 billion barrels for the first time in one year. Despite material shortage, an all-time high of 39,778 wells were drilled, with a record-smashing 6,877 wildcats completed—"beyond the imagination of most exploration men in prewar days."[207] Output of gasoline, distillates, fuel oil, and other products broke all records. The tight tanker situation which had caused so much trouble the year before was relieved by the release of Maritime Commission ships and the appearance of large new vessels just built. Over 5,500 miles of new crude-oil pipe line were built, and other transport facilities increased so as to be adequate. Then the winter was so mild as to cut demand. And the world fuel (coal) situation had so improved as to take the pressure off fuel oil. So great was the supply of fuel oil that storage became a problem; refiners had to seek a way to reduce runs, and prices were progressively reduced.

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[203] *Oil Gas J.*, Jan. 13, 1949.

[204] *Natl. Petroleum News*, Jan. 19, 1949.

[205] *The New York Times*, Feb. 29, 1949.

[206] American Petroleum Institute News Release, Mar. 7, 1949.

Indeed, by the end of the year oil was in oversupply although the "surplus in sight" was termed small. As crude-oil prices became softer, the Texas Railroad Commission shut down certain fields, announcing the action as a continuing "calling of the roll of oil fields" in its efforts over the years to prevent wasteful flaring into the air of gas.[208] Allowable output for Texas was reduced about 275,000 bbl daily from the state's all-time high production of 2,710,000 bbl a day.[209] Oklahoma and Kansas crude-oil allowable production for February was cut.[209] Imports from the Middle East, which had risen to 100,000 daily late in 1948, began to be substantially reduced—announced as another sign of the "end of the postwar oil shortage in the United States."[209] In February, also, substantial cutbacks were made in Venezuelan production.[210] By April, Middle East oil output was being reduced.[211] On Apr. 1 all restrictions on petroleum exports under the licensing law were removed.[212]

Exit, badly crippled, another oil shortage scare!

By May there were some 900,000 bbl a day of shut-in crude-oil production in the United States. That means that the industry's exploration and development program succeeded not only in catching up to consumption increases but in building up almost half of the excess domestic production of 2 million barrels daily that the military asked in the interest of national security.[213]

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[207] *Oil Gas J.*, Jan. 27, 1949.

[208] *Oil Gas J.*, Dec. 23, 1948.

[209] *Oil Gas J.*, Feb. 3, 1949.

[210] *Oil Gas J.*, Mar. 10, 1949.

[211] *The New York Times*, Apr. 15, 1949.

[212] *Oil Gas J.*, May 26, 1949.

Despite the "ending of the oil shortage," the new Eighty-first Congress did not lose its interest in oil. Before it for consideration were new proposals for oil investigations, for pipe-line divorcement, for stricter regulation of imports, for studies of the merits of the Interstate Oil Compact Commission and the Connolly Hot Oil Act, for stand-by rationing powers and a host of other matters affecting the petroleum industry.[214] And in its hands was placed the "sizzling" final report of the Senate Small Business (Wherry) Committee, attacking conservation laws and charging oil-industry domination by monopolistic integrated companies.[215] Wherry declared that the shortage of the previous winter could have been averted if the producing states had allowed their wells to flow and that oil-conservation policies "form a perfect pattern of monopolistic control over oil production, the distribution thereof among refiners, and ultimately the price paid by the public."

Also in Congress's hands was placed Secretary Krug's annual report on the Bureau of Mines synthetic-fuels research program, in which he again advocated immediate development of a synthetic-liquid-fuels industry, government financed but privately owned and operated, and urging enactment of legislation, reintroduced, that would accelerate the founding of this industry, thus assuring supply of oil adequate "for centuries."[216]

But somehow such proposals had lost some of their old-time punch and glamour. It was like a fourth act. The villain of the piece—the Cold War–Cold Winter oil-shortage scare—had exited dying at the end of the third, a victim of oil industry's great "battle of supply." The show wasn't the same without him.

9. They Always Find the Oil

As one reviews the history of oil-shortage scares, one finds a strange assortment of causes. These may be given as follows:

1. Existing facts of production versus supply
2. Interpretations of existing facts

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[213] *The New York Times*, May 8, 1949.

[214] *Natl. Petroleum News*, Feb. 2, 1949.

[215] *Oil Gas J.*, Feb. 3, 1949; *The New York Times*, Feb. 1, 1949.

[216] *Oil Gas J.*, Feb. 10, 1949.

    a. By qualified oilmen
    b. By qualified government authorities
3. Politics
4. Security
5. International politics

And often sensationalism and public confusion have tended to aggravate the patient's condition.

Usually the existing facts are about like this: Consumption goes on a tear either because of new consumption agencies such as the automobile and oil-burning ships or because of the combined growth of several or of many such agencies at one and the same time—or war. This consumptive force puts a pressure on supply. It either outruns supply for a time or creates a situation where supply and demand run a pretty close race.

During both world wars, when United States oil supply was heavily drawn upon—"drained" is the popular word used—there were shortage scares. During both conflicts we provided the bulk of the Allied demand. During both, prices were pegged. In each, all-time high peacetime consumption records were smashed—for in modern warfare oil became ammunition both on the battle front and on the home front. In neither case, however, did an oil shortage actually materialize.

Right after both wars, peacetime consumption—on each occasion apparently taking the authorities more or less by surprise—soon outstripped even the phenomenal war demand. After both, the big question mark—shortage?—loomed because supply and demand were running close. After both, the natural economic manifestation was rising prices. Full-scale shortage scares developed. But did actual shortages exist?

Both postwar scares were astoundingly parallel as to causes and manifestations. The "viewing with alarm" was done by officials of almost the same departments for the same reasons and with almost identical logic. Drastic measures to "save us" from being a "have-not" oil nation were never taken. They weren't necessary. The shortage scare was drowned in a flood of oil.

When the Second World War began, America's oil preparedness was an impressive fact. Would this have been the case had the many plans calling for government intervention to meet expectation of shortage after the First World War been adopted? By the record the answer is no. Measures to "protect" rather than "develop" would have been in error. For it was the industry's vigorous, free development that made it possible for all demands to be met during the interwar period—its phenomenal technological and scientific progress and its expansion, necessary if the increasing need was to be filled.

That a succession of new pools and fields arrived in the 1920's was not solely due to the great increase in drilling and wildcat operations spurred on by the shortage scare. In this period, subsurface geology, paleontology (study of fossils found in well cuttings), and geophysics (use of instruments such as the seismograph, gravimeter, and magnetometer in oil finding)—new techniques in exploration—came into wide use and directly brought about the discovery of new pools and fields. Improvement of materials and the development of new techniques in drilling made it possible to put wells down to deeper reservoirs and thus also stimulated new discoveries.

Within a few years, exploration as practiced in the oil industry was revolutionized. It changed from a haphazard to a scientific operation. These technological advances in the field made it possible better to define limits of underground reservoirs and to compute how many barrels of oil each pool might produce.

It was estimated in 1944 that the advances in the science of petroleum production alone had added 17 billion barrels of oil to the recovery ultimately expected from proven fields, and of the 20 billion barrels in reserve at that time 11 billion barrels were attributable to improved technology.[217] In the field of refining technology, cracking and other processes made it possible to increase yields of products in greatest demand and thus to conserve crude-oil reserves.

Technology has been called the "great multiplier" of our oil reserves. This process is dynamic; each technique is constantly undergoing improvement which accelerates its advance and in doing so increases proved reserves.

Gasoline prices, about which there was such a furor during the John Bull scare, never reached Senator La Follette's dollar a gallon prediction—not by a mile. The price rose from an average of 25.4 cents in 1919 to 29.7 cents in 1920. During the latter part of 1920 and early 1921, it went to 33 cents in many cities. It averaged 26.1 cents in 1921. At the close of 1921, it was around 25 cents a gallon. When Senator La Follette started his investigation in the middle of 1922, the price had risen again to 27.1 cents on an average. When he predicted dollar gasoline in April, 1923, it had dropped to 24 cents. It never has been as high as that since. The average price for the years 1923 to 1926 was around 20 cents. By 1930, it had dropped to 16.1 cents and in 1931 to 12.9 cents. During the intervening years through 1939, it ranged between a little over 11 cents and slightly under 15 cents. During the Second World War—and until OPA finally lifted ceilings in July, 1946—the average gasoline price was practically unchanged at around 14.5 cents. It gradually rose during the remainder of 1946 and in 1947 and 1948 to as high as 21 cents.

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[217] Lovejoy, John M., Production Technology, in "Our Oil Resources," 1st ed., p. 97, Leonard M. Fanning, ed., McGraw-Hill Book Company, Inc., New York, 1945.

One is struck by the fact that sometimes benefits (in the way of incentive) accrue from a shortage scare. Beyond question, the scare of the early 1920's improved our position in relation to foreign oil production and reserves.

It is a striking fact that, largely because of diplomatic backing given them in this period, American oil companies gained a foothold and today are active in foreign countries all over the globe. Indeed, much of the available knowledge of oil prospects in many inaccessible and undeveloped regions of the earth stems back to far-flung American exploratory ventures of the twenties. American geologists went into virtually every country believed to have oil possibilities—if they were permitted entry. Many new producing areas in which American capital participated were discovered during the first postwar decade, and momentum and perseverance carried this activity into the 1930's, resulting in the important American operations in Saudi Arabia, Bahrein Island, and Kuwait under the leadership of The Texas Company, Standard Oil Company of California, and Gulf Oil Corporation. Americans played a big part in increasing world oil reserves until today they total 78.3 billion barrels (including an estimated 28 billion in the United States).[218] That is twenty-one times as much as the world produces annually.

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[218] DeGolyer, E., *Oil Gas J.*, Dec. 30, 1948.

In many respects, the pressure on American oil interests to increase their exploratory and development operations in Latin-American and other foreign countries during the Cold War–Cold Winter scare was similar to that during the John Bull scare. Indeed, our government issued a mandate to American companies similar to that after the First World War. "Go out and find more oil," and added a line to its Good Neighbors, "Let our experienced industry help you find more, too." Again as in the previous postwar period, wherever American oil interests had access they expanded their foreign oil exploration, producing transportation and refining operations. With oil supply today, it *is* one world.

Another parallel between the two postwar scares might be pointed out. In the first case the supply problem was licked by the American oilman's drill at home—by the bringing in of a host of Cushings—whereas the accent had been on the need of foreign supplies to offset "failing" domestic resources. The emphasis was the same during the 1946 to 1948 postwar scare. Nevertheless, again it was the amazing oil discoveries in the United States—the Benedum and other Texas fields, the offshore successes in the Gulf of Mexico off Louisiana and many other new fields opened up in that state, in New Mexico, Oklahoma, and California—that actually put supply ahead in its race with demand. In both cases, however, important new supply sources were opened up by Americans in foreign countries as well.

Unarguable as is the cold, hard fact of oil shortage when gas for your car or fuel for your oil burner is in any way cut off or rationed, the fact of oil shortage is sometimes debatable—as in the case of the Cold Winter scare. Existing facts pointed to tremendously increased consumption putting a great pressure on supply. The actual shortages, again as in 1941 and 1943, were in dislocation or lack of transportation during peak gasoline and fuel-oil seasons. Their cause also lay, as during the war, in not enough steel to permit the industry to drill the wells, enlarge refineries, and build the pipe lines, tankers, barges, and tank cars needed, fast enough. In fact, one is almost tempted to designate the Cold Winter "oil shortage" a transportation and steel shortage complicated by an abnormal winter.

As to interpretation of the existing facts, the oil people, although urging consumers to conserve gas and fuel oil and in some cases showing alarm, were as usual more optimistic over meeting the demand than government authorities. While all the latter were not pessimists, there were those who certainly were. The range of interpretation of the facts lay anywhere between Secretary Krug's assertion that the demand for petroleum was so great as to constitute a drain on American oil wells, endangering future production, and the rejoinder of the Independent Petroleum Association of America, taking issue with government statements that the nation's petroleum supply was short.

The record shows that qualified industry authorities have always expressed confidence in private industry meeting oil demand, present and future. Qualified government authorities, for the most part—having, it might erroneously be said, the national interest in their "exclusive" keeping—showed less confidence of that. They showed it after the First World War by their support of a project for a government company to go into the oil business and finance American companies all over the world. They showed it by advocating after the Second World War the immediate commercial development of a synthetic-liquid-fuels business in the United States.

The government's program started out as a Bureau of Mines 30-million-dollar five-year research job on synthetic liquid fuels from coal, lignite, and oil shale. It emerged during the Second World War oil-shortage scare in 1944. The ante was raised during the Cold War–Cold Weather scare to a 30-million-dollar three-year continuing program. This was still for research. Then came the proposals for a short-range commercial program involving about 400 million dollars and a long-range one calling for 9 billion dollars.

Indeed, in following the progress of synthetic-fuels proposals one might say that synthetics mushroomed in about direct ratio to oil-shortage scare.

The political element in oil-shortage scares is considerable. A scare is "duck soup" for politicians. Oil shortage means denial, higher prices, for their constituents. Inevitably it is the work of monopoly! Congressional committee investigations provide a platform for politicians to sound off from.

Demands for government control, for more restrictions on the industry, for throwing conservation overboard flow readily from politicians' lips. They serve to promote, rather than allay, fear. Moreover, such proposals hold no assurance comparable with the one inherent in the continued free operation of the oil industry both at home and abroad, if the record means anything. The American oil industry has always found the oil. The danger lies in a scare scaring the public into support of measures that would hamstring the industry and thus create actual future shortage.

"Unfortunately, our legislative processes here do not encourage either clarity or strength, and they certainly do not seem to induce calm deliberation of the problem," James Reston, *New York Times* Washington correspondent, wrote in discussing a decision facing the United States in foreign policy.

One is struck by the aptness of this observation in connection with the legislative proposals that have sprung out of oil-shortage scares.

"We legislate, in short, in an atmosphere of crisis," Reston concluded.

Therein lies the *real* danger in times of oil-shortage scare.

Have politicians the idea that this country faces periodical or perpetual oil shortages? There is evidence of it. Representative John McCormack of Massachusetts expressed this belief, as follows: "The tremendous growth in demand for petroleum and petroleum products during and since the war has transformed the supply position of the United States from one of chronic surplus to current and probably future scarcity. As a result, consumers in the United States are no longer assured of the availability of oil supplies adequate to meet their needs. Local and even widespread national shortages of fuel in periods of seasonably high demand are periodically threatened."

Acceptance of this view overlooks the record of American success in oil discovery and invention. To credit it one must ignore the drive and dynamics of private petroleum enterprise, which refused to be satisfied with the prophecy in 1920 that there was only a reserve of 7.2 billion barrels in this country, which since that time has actually delivered 32.8 billion barrels and, on top of that, has raised proved reserves to 27 billion barrels.

The evidence points to the military contributing heavily to oil-shortage scares. This is not necessarily said in criticism. There are extenuating circumstances, one might say, when the guardians of the nation's security fear shortage during war—and during a "cold war." The security element in the oil-shortage scares of both wars was, on the record, substantial. During both wars, it was a race between supply and demand right up to the finish line, and it might have been a tighter squeak in both cases if war had continued a year or two longer. However, the fact is that the essential needs for more and more oil as the wars went on *were* met and that supply *was* built up to a crescendo which contributed heavily to certain, and at a given point, swift victory.[219]

The military contributed to the oil-shortage psychosis in peacetime, as well, as we have seen during the John Bull scare and the Cold War scare. As far back as August, 1946, when the State Department radio debaters touched on a coming oil shortage, the attention of the oil industry was directed to the possibility of having to subordinate some of its freedom of enterprise to military expediency. It was pointed out that the industry was confronted with an important and complicated military supply problem.

The activities of certain government departments and boards indicated a strong military influence in matters pertaining to oil supply. This influence also was paramount in considerations regarding oil sources by the National Security Resources Board, created under the National Security Act of 1947, which provided for the unification of the armed services.

As tension mounted during the Cold War, military-sponsored programs such as synthetic fuels, stock piling, and the like, sincerely based on views as to our security needs, received increased attention. Naturally they made newspaper headlines. Oil scare became as one with war scare.

The problem of meeting oil demand during wartime has twice before been solved by basically adhering to, and encouraging, private operation. It has been shown that in such emergencies government and industry can work together as a team—and can head off an oil shortage if one appears to be looming on the horizon.

On the record, the question is whether danger to our security does not lie in too much sacrifice of free enterprise to military expediency in so far as oil supply is concerned.

One is reminded of a statement by C. E. Wilson, president of the General Electric Company, that there is just one material or commodity we have in great abundance—"know-how."[220] He described it as almost the only thing worth stock piling. American oil know-how is the military's best bet. Again, the record proves it.[221]

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[219] Oil for Victory, editors of *Look*, 1946.

[220] *The New York Times*, Apr. 30, 1949.

[221] "A History of the Petroleum Administration for War, 1941–1945."

International politics in an oil-shortage scare stems from the reasoning that oil is power. This can be argued both ways in peacetime, for it is questionable whether simply the possession of the oil commodity means much unless there are people to purchase it the world over. The possession of oil for the waging of war is another matter.

Professor Kirtley F. Mather of Harvard University has called petroleum strategic mineral number one in world affairs. "Almost everywhere we look, as we try to utilize the earth's resources for the benefit of mankind, petroleum holds a central if not dominating position," he said. "Indispensable to our civilization, it is a compelling factor in relations between the major powers."

Competition for control of Middle East oil riches is an important element in the tension between the United States and Russia. The far-flung holdings of British oil companies are fundamental to the foreign policy and economic planning of Great Britain. Middle East oil has significant bearing on American interest in the future of Palestine. Not even the Good Neighbor policy in the Western Hemisphere can escape the implications of the presence of vast oil reserves in several of the Latin-American republics.

One reason for all of this, Professor Mather pointed out, is that in many fields there is at present no adequate substitute for oil. Regardless of any developments that now seem likely with respect to atomic energy, oil will continue for many years to be a primary source of power for industrial nations. It will also be a basic raw material for numerous chemical industries. Another reason is that it is an exhaustible resource.

It is not surprising, therefore, that oil has taken on the symbolism of power, influencing the acts of nations, and that an oil-shortage scare can be a powerful weapon in the hands of politicians and diplomats. The question that nations must answer is: Can the world's oil reserves, which are potentially great and adequate, be equitably and peacefully developed and marketed for the benefit of all countries?

Oil-shortage scares have been outrageously used for propaganda purposes. What the public wants is information—the truth. When it gets a welter of interpretations of facts, it becomes confused and misunderstands. It fails to weigh the elements creating the scare. The next easy step is for it to become a fall guy *for* the scare, thus contributing to its fever.

Sensationalism is all that is needed to complete the picture of distraction. From the drilling of the Drake well in Pennsylvania in 1859, which marked the beginning of the American oil industry, oil and its mysterious source, its capacity to enrich and to impoverish, its identity with the greatest and most pilloried of industrial monopolies when monopolies flourished, its sharing of our daily life, and its terrible power seemingly to go so far as to make nations war over it—these singly inspire sensationalism and collectively keep oil perpetually boiling.

Fortunately, when an oil-shortage scare boils over, it douses its own flame. At any rate, that is the record to date.

They always find the oil!

APPENDIX

A National Oil Policy for the United States

LETTER OF SUBMITTAL, NATIONAL PETROLEUM COUNCIL

January 13, 1949

Honorable J. A. Krug
Secretary of the Interior
Washington, D. C.

My dear Mr. Secretary:

Pursuant to your request of July 3, 1948, that I appoint a committee to restudy and supplement the report on A Petroleum Policy for the United States adopted on October 24, 1945, by the Petroleum Industry War Council, I have the honor to transmit to you herewith a report on A National Oil Policy for the United States prepared by the National Oil Policy Committee of the National Petroleum Council and unanimously approved by the Council on January 13, 1949.

In the preparation of this report the Council has kept actively in mind the importance of the assignment, as expressed in the following quotation from your letter of July 3:

> As you are aware, during the past year the subject of national oil policy has been a matter for intensive consideration and discussion by the several branches of the government, the public, and the petroleum industry. The immense importance of petroleum in the world today, combined with changing facts and circumstances, has focused the national attention on this important area of the economy. Several committees of the Congress, many high officials of the executive branch, and a number of important groups of citizens have called for prompt formulation and enunciation of the broad principles of sound national oil policy.

> However, if such policy is to be informed and in the public interest, it is essential that the wisdom and experience of the petroleum industry be brought to bear on the subject, and I therefore request the National Petroleum Council . . . to appoint a temporary committee to restudy and supplement the National Oil Policy Report referred to in the Council's resolution of January 13, 1947, and to present its views and recommendations to the Council. It is believed that such a report will be of great service to the various agencies of our government in the executive branch as well as to the Congress.

The policies outlined in this report are designed to promote the welfare and security of our country through the maintenance of a healthy petroleum industry which is essential to this objective.

Respectfully submitted,

Walter S. Hallanan, Chairman
National Petroleum Council

Enc.

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